TESTS OF LEAD, ACID & NICKEL IRON ALKALINE STORAGE BATTERIES

BY

L. C. ANDERSON

J. H. KUEHNE

ARMOUR INSTITUTE OF TECHNOLOGY

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COMPARATIVE TESTS
OF
LEAD/LEAD ACID AND NICKEL/IRON ALKALINE
STORAGE BATTERIES.

A THESIS

PRESENTED BY

LEONARD C. ANDERSON

AND

JOHN H. KUEHNE

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INTRODUCTION.

The object of this thesis is to make comparative tests of two types of batteries, namely: the lead/lead acid and the nickel/iron alkaline types. The lead/lead acid type, consisting of three cells, which we used was furnished for this purpose thru the courtesy of the Vivax Battery Company. It is designated by the manufacturers as their type No. 19, N P; used for lighting and ignition work. The nickel/iron alkaline type of battery, consisting of five cells, was purchased from the Edison Storage Battery Company. It is known as their "B4" type; used especially for the lighting and ignition work in connection with automobiles.

In making these tests, we endeavored to follow as closely as possible conditions that the batteries would meet in actual practice. To be more positive of our results, all instruments used in connection with this work were calibrated and the errors corrected.

The tests made were on commercial cells; the same as those sold to the general public and not cells put out especially for testing work. The batteries were discharged at varieous rates keeping the current constant during any one run. The batteries were always charged at normal rate. Tests were made with the batteries remaining idle a long period and then discharged to determine the amount of leakage and local action in the respective cells. The results of all the different tests were properly tabulated and average curves were drawn for the different experiments.

In the performing of this thesis, the controlling object in view, on the part of the authors, was to determine the true performance of the batteries. The work has been carried on at all times with the unbiased feeling of experimenters interested only in getting at the facts.

SHORT HISTORY OF ALKALINE STORAGE BATTERY.

The alkaline storage battery, which until a few years ago was not a commercial success, was first invented and patented in the year 1881 by F. de Lalande and G. Chaperon. They, however, patented it as a primary cell with a clause in their original patent saying, "The piles are reversible, that is to say, capable of being recharged by an electric current of sufficient electromotive force." The cell patented by them consisted of a positive of iron, copper or other metal or of gas-retort carbon surrounded with copper oxide, which could be agglomerated by one of several described processes, with a negative of zinc, preferably amalgamated, and an electrolyte of ten per cent to fifty per cent solution of caustic soda or potash.

Three years later, the same men took out

another patent on their cell in which the construction is specified in detail, and several modifications introduced. Cast-iron is given preference as the material for the positive electrode, which also serves as the outer vessel and contains a layer of copper oxide in the bottom thereof. As before, zinc constitutes the negative electrode, but it is wholly immersed in the electrolyte by mean of a supporting rod of amalgamated brass. For use in cells to be re-charged, a special form of negative is proposed, consisting of a zinc or brass tray containing mercury with which the deposited zinc forms an amalgam.

In the year 1884, E. Commelin, G. Bailhache, A. de Virloy and L. de Bousignac took out a patent on substantially the same com-

bination as that of Lalande and Chaperon; but entirely confining themselves to its use as a storage cell. In 1886, the same inventors in conjunction with C. Desmazures obtained another patent for various modification of their cell. From 1889 to 1891, several patents were taken out by J. B. Entz and W. A. Phillips for a new type of copper oxide positive electrode. It was made up from a composite wire consisting of a copper wire core, then a layer of copper oxide, then a network of finer copper wires, in the meshes of which the copper oxide was imbedded. The negative electrode consisted of a perforated sheet of tinned iron bent double on itself, and in the space thus formed between the two sides, the positive electrode was placed.

Although copper is the only metal whose

oxide has been employed on any practical scale as the positive active material in an alkaline electrolyte, many others have been proposed and tried. In 1886, H. Aron took out a German patent for an alkaline cell with zinc and oxide of mercury as the respective negative and positive active materials.

In 1900, Edison patented his first alkaline battery. It consisted of a combination of cadmium/copper oxide. In this type of cell, the positive electrode consisted of copper oxide placed in pockets or recesses produced in a thin sheet of perforated nickel or nickel-plated iron by stamping it up. The negative active material consisted of finely divided metallic cadmium prepared by deposition upon a platinum wire from a solution of cadmium sulphate. After washing it was

packed into recesses in plates similar to those used for the positive. The electrolyte recommended was a ten per cent solution of sodic hydrate.

In 1901, Edison filed another specification which relates to an iron/nickel oxide combination. In this cell, the positive and negative plates are mechanically alike and differ only in the chemical pockets. The plates are formed of a comparatively thin sheet of steel, 0.024 inches in thickness, in which rectangular holes are stamped, so as to leave a grid or frame somewhat resembling a window frame. Each opening or recess is filled with a pocket or shallow box containing the active material. The pockets are perforated with numerous small holes to admit the electrolyte, but entirely conceals the

the contained active material from view.

The active material is made in the form of rectangular cakes or briquettes around each of which is placed the thin sheet of perforated steel which has a thickness of 0.003 inches. The positive briquettes are made by mixing a finely divided compound of iron, obtained by a special chemical process, with a nearly equal volume of thin flakes of graphite. The graphite does not enter into any of the chemical actions, but increases the conductivity of the briquettes. The negative briquettes are made by similarly mixing a finely divided compound of nickel obtained by special chemical means, with a nearly equal bulk of fine flakes of graphite and solidifying the mixture in a mould into briquettes of the same size as the positive

having a surface area three inches by one half an inch.

The assembled plates, consisting of a suitable number of positive and negative plates and separated from each other by thin sheets of perforated hard rubber, are placed in a vessel of sheet metal containing the potash solution. The seams of the steel containing vessel are then welded together by a special solder which was not affected by the alkaline electrolyte.

After a short period, Edison withdrew the battery from the market and started experimenting for a more perfect storage battery. In 1908, he put on the market his present "A" type Edison battery. In 1910, there were five sizes of cells put out namely: "A4", "A6", "A8", for automobiles, street-cars and other

heavy work; and "B2" and "B4" for ignition and other work of the lighter nature.

Edison changed the type of the positive plate in the cells that he put on the market in 1908 from what he put out in 1901. From flat rectangular pockets filled with nickel flake, he changed to long cylindrical tubes containing the nickel flake. In this new type of battery, the active materials are nickel hydrate and an oxide of iron, respectively in the positive and negative electrodes; the electrolyte being a twenty-one per cent solution of caustic potash in water.

SHORT HISTORY OF ACID STORAGE BATTERY.

In 1801, Gautherot, a French scientist, discovered that secondary currents existed in platinum or silver wires which had been used to decompose saline water in the Voltaic cell. A short time after Gautherot made this discovery, Ritter made the first secondary battery. The battery, inactive in itself, after having been submitted to the action of a voltaic battery of a greater number of cells than that of which it was composed, could give for some moments a current in the opposite direction to that of the voltaic battery. Ritter's secondary battery consisted of discs of copper separated by circular pieces of cloth moistened in saline water or sal-ammoniac.

De La Rive, about the year 1826, discovered that a secondary current arose from platinum plates in a voltameter filled with

water slightly acidulated by sulphuric acid. This current was at first attributed simply to physical effect produced by the primary current, to a special polarization of the plates under its influence, and this current received the name of Polarization Current, a term which has remained in scientific use. In 1860, a secondary element was constructed by Plante by rolling two long wide lead plates into a coil, separating one from the other by a thick cloth, and then immersing them in a glass jar full of water acidulated with a tenth part of sulphuric acid.

Later on, Plante modified the method of separating the lead plates. Instead of using thick cloth, he used narrow strips of India rubber to separate the sheets. This had the advantage that the rubber strips were not af-

fected in the acidulated water and that they covered only a very small portion of the surfaces of the electrodes.

The first patent to be issued in the United States for the storage battery was in 1866 and was granted to George C. Percival. The battery consisted of a wooden box, divided into two parts by a porous partition and filled with a suitable conducting powder, moistened with dilute sulphurice acid; two lead plates placed on opposite sides of the box constituted the terminals. In 1879, R. L. Metzger partially overcame the tedious process of formation of the Plante element by mechanically applying to a lead plate active material in the form of a paste of lead oxide.

It remained for Camille Faure to make known this improvement when he obtained, in

1881, patents on a similar process, which is now known as the Faure system. The first experiment by Faure was to cover an ordinary Plante plate with lead oxide. He, later on, improved on this method by using an antimonious lead grid, with a paste of red lead and sulphuric acid for the positive, and litharge and sulphuric acid for the negative.

On account of the advantages of each of the two systems, namely: Plante and Faure, the manufacturers are endeavoring to produce a battery which will combine the advantages of both with none of the disadvantages of either.

THE EDISON BATTERY B4 TYPE.

The "B4" type of the Edison Battery Company's storage batteries is one of their smaller types and is used chiefly for ignition and lighting purposes. The battery set, which complete consists of five cells, is rated, at normal values, at eighty ampere-hours and an e.m.f. of six and one-half volts. The cell consists of a retaining can of thin nickel-plated steel which contains the plates and electrolyte. The elements consist of four positive plates, each made up of fifteen round tubes containing nickel hydrate, associated with five negative plates, each made up of sixteen flat pockets containing iron oxide. The tubes and pockets for retaining the respective active materials are very thin steel perforated with a large number of small holes for enabling the electrolyte to gain free

access to the oxide during all processes of electrical activity.

These tubes and pockets are fastened securely to their respective plates thus insuring permanent and rigid construction. The plates of each group are hung on a connecting rod perpendicular to, but integral, with, the pole. They are separated from each other by nickel-plated steel spacing washers.

The outer surfaces of the outer plates are insulated from the retaining can by thin sheets of hard rubber. On the sides and bottom of the plates, there are special rubber pieces which have grooves that fit the plates, thus separating them from the retaining can. Between the plates there are small rubber rods which keep the plates spaced as well as insulated. All the seams of the can are welded bv an autogenous process.

On the cover of the retaining can, there are three mountings; two of which are the stuffing boxes thru which the positive and the negative poles extend; the third mounting can be unscrewed to allow the refilling of the cell with electrolyte and for the adding of distilled water to take the place of that which evaporates. This mounting is called the separator. It is a valve which separates the spray from the escaping gas while the battery is charging.

In the assembled battery, which consists of five cells, each cell is held securely in place and from contact with adjacent cells by means of a small rubber button. This extends thru a slat on the side of the tray and fits over an emboss pressed out on the sides of the can. The bottoms of the cells are held in position by small buttons pro-

truding from wooden blocks fastened to the bottom slats of the tray. In the bottom of each cell are small indentations which fit over these buttons thereby affording a very rigid support. The wooden tray and assembled cells fit into a black enameled steel case with a hinged cover.

The chemical reactions which take place in the Edison cell become quite complicated, and it is still uncertain as to the exact conditions which exist. It is understood, however, that the passage of current in either direction decomposes the electrolyte into "K" and "OH".

The following equations of charge and discharge, which were obtained directly from the Edison Storage Battery Co., represent the probable chemical changes:

DISCHARGE:- $(3Fe+8OH)+(8K+6NiO_2)=Fe_3O_4+(4H_2O+4K_2O)+2Ni_3O_4$, and as a secondary reaction $4H_2O$ unites with $4K_2O$, forming $8KOH$, the same amount of electrolyte as was decomposed to begin with.

CHARGE:- $(Fe_3O_4+8K)+(2Ni_3O_4+8OH)=3Fe+(4K_2O+4H_2O)+6NiO_2$.

And again $4K_2O$ equals $8KOH$.

Edison Storage Battery.

Type B4

- Weights -

Of Set Complete	41.58	pounds
Five Cells and Connectors	34.74	"
Enclosing Case for Set	4.74	"
Wooden Tray and Insulators	2.10	"
One Cell Complete	6.95	"
One Positive Plate Complete	.51	"
Four Positive Plates Complete	2.04	"
One Positive Plate Grid	.06	"
Four Positive Plate Grids	.24	"
One Positive Tube Complete	.03	"
Fifteen Positive Tubes Complete (1 Plate)	.45	"
Positive Active Material in Cell	1.10	"
One Negative Plate Complete	.295	"
Five Negative Plates Complete	1.475	"
One Negative Plate Grid	.055	"
Five Negative Plate Grids	.275	"
One Negative Pocket Complete	.015	"
Sixtenn Negative Pockets Complete (1 Plate)	.240	"
Negative Active Material in Cell	1.05	"

Edison Storage Battery.

Type B4

- Dimensions -

Of cell (inside)	$2\frac{15}{32}$"x$4\frac{15}{32}$"x$6\frac{1}{4}$"
Thickness of Metal	$\frac{1}{32}$"
Height from bottom of Cell (outside) to top of Binding Pole	$7\frac{19}{32}$"
Distance of Plates from bottom of Cell	$\frac{15}{32}$"
Distance between adjacent Plates	$\frac{3}{64}$"
Distance between Plate and side of Cell	$\frac{1}{16}$"
Of Negative Plate Grid	$4\frac{25}{32}$"x$4\frac{3}{4}$"x $\frac{1}{32}$"
Of Positive Plate Grid	$4\frac{25}{32}$"x$4\frac{3}{4}$"x $\frac{1}{32}$"
Of Negative Pocket	$\frac{1}{8}$"x $\frac{1}{2}$"x$2\frac{1}{3}$"
Of Positive Tube	$4\frac{9}{32}$"x$\frac{1}{4}$" (diam)
Of Metal Case Holder for Set	$15\frac{1}{4}$" x$6\frac{1}{2}$"x$8\frac{3}{4}$"

THE VIVAX BATTERY NP NO. 19 TYPE.

The acid storage battery, which we used in comparison with the alkaline battery, was manufactured by the Vivax Storage Battery Company located at Chicago, Ill. The battery is designated by the manufacturers as their NP No. 19 type and is used for ignition and lighting purposes. It is rated at 100 ampere-hours capacity at what is called ignition rate which is usually figured at one ampere discharging rate, and rated at 80 ampere hour at the automobile lighting rates which vary from five to twelve amperes. The set consists of three cells which gives an e.m.f. of six volts. Each cell is composed o a retaining jar of hard rubber, four negative plates and three positive plates, and the electrolyte, and insulators.

The Plates are of the usual Faure type and the paste a very hard dense mixture of lead oxides formed by a special forming process. The grids, which hold the lead oxide paste, and the cross strap terminals are made of an alloy which consists of six per cent antimony and ninety-four per cent lead. The electrolyte consists of sulphuric acid and distilled water. The acid density at full charge is 1.275 specific gravity or 31.1 Beaume. The insulators consist of wood sheets ribbed on one side and perforated hard rubber sheets which have a thickness of one sixty-fourth of an inch.

The perforated hard rubber sheet is placed against the ribbed side of the wood sheet and this combination is installed between the positive and negative plates. The

rubber sheet is next to the positive plate and the flat side of the wood separators toward the negative plate. In the bottom of the cell, there is a ribbed insulator which keeps the plates from touching the bottom of the retaining jar.

The positive and negative plates are held in position by their respective cross strap terminals, the poles of which extend up thru stuffing boxes in the cover and form the respective binding posts. On the cover, there is a cap which can be unscrewed for the purpose of adding electrolyte and also so that one can readily take the specific gravity of the acid. There is a small hole bored in top of the cap which allows the gas to escap during the charging process.

The three cells, which comprise this

type of battery, are held in a wooden box which can be easily carried by means of a rubber handle attached thereto.

The elements of the battery are sponge lead (Pb) for the negative, and peroxide of lead (Pb 02) for the positive. The peroxide plate is of a brown chocolate color and the lead sponge is a light gray. When the battery discharges, the electric current decomposes the water in the electrolyte, liberating hydrogen and oxygen, the first being evolved at the positive or peroxide element, and the oxygen at the negative or sponge lead plate. The oxygen and hydrogen, at the instant of liberation, are chemically more active than in their fixed or ordinary state, and combine more readily with other substances. The nascent hydrogen combines with certain molecules of oxygen in the lead peroxide,

forming water, and the abstraction of these molecules of oxygen reduces the degree of oxydization of the peroxide, and changes it into lead oxide(PbO). The oxygen liberated at the negative pole combines with the negative or lead plate to form lead oxide (PbO). Therefore complete discharge would change the positive and negative elements into the same compound, the voltaic couple would no longer exist, and no further discharge could be obtained from the battery.

If, however, a charging current be sent thru the battery in a direction opposite to that in which current flowed on discharge, the gases of decomposition are liberated also oppositely, the oxygen being formed at the positive and the hydrogen at the negative plates. The oxygen at the positive pole com-

bines with the lead oxide, adding a molecule of oxygen and changing the element to lead peroxide, while the hydrogen combines with the molecule of oxygen in the negative element to form water, and thus abstracts the oxygen from the negative plate, turning it back to lead. The battery, is then, when fully charged, exactly in the same state as before, and becomes again an active voltaic couple. On discharge the lead peroxide and sponge lead change directly into lead sulphate.

Changes also take place in the electrolyte during charge and discharge. On charge, the SO_3 in combination with the active material and forming the lead sulphate, is given up to the liquid, which therefore gains weight and its density increases. On discharge, the converse action takes place;

the SO_3 is taken up by the lead and lead peroxide to form sulphate, and the density of the liquid decreases. The equations which expresses the changes are as follows:

←-------charge

(a) $PbO_2 + H_2SO_4 = PbSO_4 + H_2O + O$

(b) $Pb + H_2SO_4 = PbSO_4 + H_2$

(c) $c = (a) + (b) = PbO_2 + Pb + 2H_2SO_4 = 2PbSO_4 + H_2O$ (2)

discharge------→

Vivax Storage Battery

Type NP No. 19

Weights

Set Complete	59.76	pounds.
Three Cells and Connectors	55.50	"
Wooden Holder and Rubber Handle	4.26	"
One Cell Complete	18.40	"
One Positive Plate Complete	1.86	"
Three Positive Plates Complete	5.58	"
One Positive Plate Grid	.57	"
Three Positive Plate Grids	1.71	"
Positive Active Material in Cell	3.87	"
Positive Cross Strap Terminal	.31	"
One Negative Plate Complete	1.38	"
Four Negative Plates Complete	5.52	"
One Negative Plate Grid	.57	"
Four Negative Plate Grids	2.28	"
Negative Active Material in Cell	3.24	"
Negative Cross Strap Terminal	.34	"
Electrolyte in Cell	2.00	"

Vivax Storage Battery

Type NP No. 19.

- Dimensions -

Of Cell (inside)	$2\frac{3}{16}$"x6"x$11\frac{3}{4}$"
Thickness of Jar	$\frac{1}{8}$"
Height from bottom of Cell (outside) to top of Binding Posts	$13\frac{1}{8}$"
Distance between Plates and bottom of Cell (inside)	$1\frac{1}{8}$"
Distance between Plate and side of Cell	$\frac{3}{64}$"
Distance between Adjacent Plates	$\frac{5}{64}$"
Of Positive Plate	$8\frac{5}{8}$"x$5\frac{5}{8}$"x $\frac{3}{16}$"
Of Negative Plate	$8\frac{5}{8}$"x$5\frac{5}{8}$"x$\frac{3}{16}$"
Of Wooden Holder for Set	8 "x$9\frac{3}{8}$"x$8\frac{5}{8}$"
Height of Complete Set	14"

CALIBRATION OF INSTRUMENTS.

The instruments we used in connection with this thesis, were calibrated before starting and after completing the thesis. The calibration was done in the testing department of the Armour Institute of Technology. For calibrating the voltmeter, we placed it in parallel with Weston's Direct Reading Laboratory Standard Voltmeter No. 33. We plotted a curve with the standard readings as abscissae and the voltmeter readings as ordinates. For calibrating the ammeters, we used Weston's Direct Reading Laboratory Standard Milli-Voltmeter No. 28 which had previously been calibrated as a standard ammeter. We placed the ammeter to be calibrated in series with the shunt of the standard instrument, and plotted curves with standard readings as abscissae and ammeter readings as ordinates.

METHOD OF PROCEDURE.

In all of the work on this thesis we always made two complete runs at the same rate, so that one would be a check on the other. A "Run" being a term given to a discharge and the following charge. In plotting the curves we used the average of the two runs as the data to be plotted.

The first test performed in connection with this work was to determine the virtual resistance of each of the batteries at the normal rate of fifteen amperes, and at certain intervals of time we took readings on thevoltmeter at discharge rates of five, fifteen, and twenty-five amperes. The readings were taken as soon as the adjustments were made, thereby keeping the interval of time between the five and fifteen ampere reading practically the same as the interval

between the fifteen and twenty-five ampere reading so that the average would always be fifteen amperes. After each reading the current was adjusted back to fifteen amperes.

To find the virtual resistance we took the difference between the ammeter readings and the difference between the voltmeter readings and dividing the second by the first, which, according to Ohm's Law, is $R=\frac{E}{I}$.

After determining the resistance we discharged the batteries at various rates ranging from five amperes up to thirty amperes, but always charged at the normal rate of fifteen amperes.

The two batteries were connected in series and charged from 110 volt mains thru a lamp rack and a carbon rheostat, the latter being used to obtain a finer adjust-

ment. A carbon rheostat was also used for the discharging resistance.

It was much more difficult to determine when the battery was fully charged than it was to determine when it was discharged. We considered the batteries as fully charged when the voltage remained constant for fifteen minutes. Specific gravity readings were also used as a check on the lead cell, but this could not be done on the Edison battery on account of the gravity of the electrolyte remaining practically constant throughout charge and discharge.

The difficulty in charging the Edison battery by voltage is that the potential will rise to an abnormal valve early in charge and remain constant for a short period

of time, misleading one to think that the state of full charge had been reached. When this abnormal rise occurs it will be noticeable during the first hour or two of charge, and is usually followed by a dropping back to normal voltage, so that, with a little experience one can easily recognize this false indication, and ignore it.

The discharge was stopped when, at the normal rate, the voltage had fallen to one volt per cell on the Edison and one and eight-tenths volts per cell on the Vivax battery. At the different rates the lower limit of voltage was increased or decreased in proportion to the average increase or decrease of the R I drop in the cell as the case may be. A table on one of the following pages will show the lower limit of voltage to which the cells were discharged.

When one battery became discharged before the other, the first was allowed to stand in a discharged condition until the second was ready for charging. When both batteries were discharged they were put on charge immediately. Under no circumstances, whether on high or low rates, was the circuit interrupted between the time discharge began until discharged. The same condition holds true on charge.

With the exception of the low rates, a run was completed in a day, the batteries usually being allowed to remain idle, but in a charged condition, over night. Owing to the fact that there is considerable loss of charge due to leakage and local action during the first few hours of idleness, the batteries were put on charge again the next morning to

make sure they were fully charged before the discharge was begun.

During all these tests no attempt was made to keep the temperature constant, the cells being left in their case the same as they would be in actual practice. The cell temperatures were noted, however, and also the room temperature, the latter being practically constant.

To get the batteries in working order we made twenty-one preliminary runs on the Edison battery and twelve on the Vivax. The first run which will appear in this work will be designated as "Run No. 1."

DATA OF TESTS.

Calibration of Weston Ammeter No.7569.

Ammeter	Standard (before)	Standard (after)
0	0.00	0.00
5	5.03	5.01
10	10.03	10.02
15	15.51	15.50
20	20.51	20.50
25	25.51	25.50
30	30.52	30.50
35	35.53	35.51
40	40.54	40.70
45	45.55	
50	51.01	

Calibration of Weston Voltmeter No.1155.

Voltmeter	Standard (before)	Standard (after)
0.0	0.00	0.00
0.5	0.52	0.52
1.0	1.02	1.00
1.5	1.54	1.51
2.0	2.07	2.01
2.5	2.56	2.51
3.0	3.04	3.00
3.5	3.55	3.52
4.0	4.05	4.02
4.5	4.55	4.52
5.0	5.06	5.02
5.5	5.56	5.51
6.0	6.06	6.00
6.5	6.55	6.50
7.0	7.04	6.99
7.5	7.55	7.43
8.0	8.06	8.00
8.5	8.55	8.49
9.0	9.06	8.99
9.5	9.56	9.49
10.0	10.06	9.99

Calibration of Weston Ammeter No. 4038.

(before beginning tests)

Ammeter	Standard	Ammeter	Standard
0.0	0.00	8.0	7.95
0.5	0.46	8.5	8.47
1.o	0.96	9.0	8.95
1.5	1.49	9.5	9.45
2.0	1.96	10.0	9.94
2.5	2.50	10.5	10.42
3.0	2.99	11.0	10.92
3.5	3.01	11.5	11.40
4.0	4.02	12.0	11.91
4.5	4.51	12.5	12.47
5.0	5.01	13.0	12.85
5.5	5.50	13.5	13.34
6.0	5.99	14.0	13.82
6.5	6.49	14.5	14.31
7.0	6.98	15.0	14.80
7.5	7.47		

Calibration of Weston Ammeter No. 4088.

(after completing tests)

Ammeter	Standard
0.0	0
2.0	1.99
3.0	3.01
4.0	4.02
5.0	5.00
6.0	6.00
7.0	7.00
8.0	7.98
9.0	8.99
10.0	10.97
11.0	10.97
12.0	11.95
13.0	12.95
14.0	13.80
15.0	14.86

Edison "B4" Type.
(5 cells)

Determination of Virtual Internal Resistance.

Run No. 1.

Time Hrs.	Temp.C°.	V@5A.	V@15A.	V@25A.	Res/cell.
0.00	24.0	7.63	7.20	6.75	.0088
0.25	24.5	6.90	6.53	6.20	.0070
0.75	26.0	6.65	6.28	5.97	.0068
1.00	26.0	6.58	6.21	5.90	.0068
2.00	29.0	6.41	6.04	5.75	.0066
2.25	30.0	6.38	6.01	5.72	.0066
2.50	30.5	6.35	5.98	5.69	.0067
3.00	32.0	6.29	5.92	5.61	.0068
3.50	33.0	6.22	5.85	5.54	.0068
4.00	34.0	6.14	5.78	5.41	.0073
4.75	34.5	6.12	5.72	5.38	.0074
5.25	37.5	5.89	5.39	4.91	.0098
5.50	38.5	5.80	5.15	4.63	.0117
5.75	39.0	5.63	4.82	3.95	.0168

Edison "B4" Type.
(5 cells)

Determination of Virtual Internal Resistance.
Run No. 2

Time Hrs.	Temp.C°	V@5A.	V@15A.	V@25A.	Res/cell.
0.00	30.5	7.32	7 10	6.62	.0070
0.25	31.0	7.06	6.71	6.40	.0066
0.75	32.0	6.78	6.47	6.19	.0059
1.25	33.0	6.66	6.30	6.02	.0064
1.75	34.0	6.56	6.21	5.95	.0061
2.75	35.5	6.42	6.08	5.79	.0063
3.00	36.0	6.38	6.03	5.77	.0061
3.25	36.5	6.34	6.00	5.72	.0062
3.50	37.0	6.31	5.97	5.67	.0064
3.75	37.5	6.27	5.90	5.60	.0067
4.00	38.0	6.23	5.88	5.57	.0066
4.25	38.5	6.21	5.82	5.50	.0071
4.50	39.0	6.16	5.77	5.43	.0073
4.75	39.5	6.11	5.71	5.36	.0075
5.00	40.0	6.07	5.66	5.28	.0079
5.25	40.5	6.01	5.57	5.16	.0085
5.50	41.0	5.93	5.45	4.99	.0094
5.75	41.5	5.81	5.22	4.59	.0122

Vivax"N P No. 19" Type.
(3 cells)

Determination of Virtual Internal Resistance.
Run No. 1

Time Hrs.	Temp.C°.	V@5A.	V@15A.	V@25A.	Res/cell.
0.00	25.0	6.58	6.26	6.05	.00883
0.25	25.0	6.23	6.11	6.00	.00384
0.50	25.0	6.22	6.10	6.00	.00367
0.75	25.0	6.22	6.10	6.00	.00367
1.00	24.9	6.20	6.08	5.99	.00350
1.50	24.8	6.19	6.07	5.98	.00350
2.50	24.5	6.12	6.00	5.91	.00350
3.50	24.5	6.03	5.92	5.80	.00384
4.00	24.5	6.00	5.89	5.78	.00367
5.00	24.6	5.86	5.71	5.60	.00434
5.75	25.0	5.68	5.52	5.37	.00650
6.00	25.2	5.61	5.40	5.22	.00650

Vivax "N P No. 19" Type
(3 cells)

Determination of Virtual Internal Resistance.
Run No. 2.

Time Hrs.	Temp.C°.	V@5A.	V@15A.	V@25A.	Res/cell.
0.00	25.8	6.40	6.45	6.25	.00250
0.25	25.7	6.22	6.11	6.01	.00350
0.50	25.7	6.22	6.10	6.01	.00350
1.50	25.3	6.18	6.07	5.98	.00333
2.00	25.2	6.15	6.04	5.95	.00333
2.50	25.0	6.11	6.00	5.90	.00333
2.75	25.0	6.10	5.99	5.90	.00333
3.50	24.9	6.03	5.91	5.81	.00366
4.00	24.7	5.98	5.86	5.75	.00383
4.50	24.6	5.92	5.79	5.67	.00416
5.00	24.7	5.85	5.70	5.58	.00450
5.50	24.9	5.74	5.59	5.43	.00516
5.75	25.0	5.68	5.50	5.33	.00583
6.00	25.2	5.58	5.40	5.18	.00666

The following table shows the voltage at which discharge was stopped. The figures are based upon the change in R I drop in the cell at the different rates:

Discharge Rate (Amperes)	Volts per cell at discharge	
	Edison	Vivax
5	1.074	1.84
10	1.038	1.82
15	1.000	1.80
20	0.964	1.78
25	0.926	1.76
30	0.888	1.74

Edison "B4" Type.
(5 cells)

Discharge at a constant rate of 5 Amperes
Run No.3.

Time in Hours	Volts	Temp.C°
0.0	7.67	20.1
0.5	7.05	20.3
1.5	6.77	20.9
2.5	6.61	21.6
3.5	6.53	22.4
4.5	6.49	23.0
5.5	6.45	23.7
6.5	6.42	24.8
7.0	6.41	25.2
8.0	6.37	25.9
9.0	6.34	26.5
10.0	6.31	27.0
11.0	6.27	27.4
12.0	6.23	27.9
13.0	6.19	28.4
14.0	6.13	29.1
15.0	6.08	29.2
16.0	6.00	29.2
17.0	5.89	29.1
18.0	5.63	29.1
18.5	5.37	29.L

Average room temp. 20.5°C

Edison "B4" Type.
(5 cells)

Charge at a constant rate of 15 Amperes.
Run No. 3

Time in hours	Volts	Temp C°
0.00	7.78	25.9
0.25	8.26	26.7
0.50	8.39	27.3
1.00	8.25	28.2
1.50	8.21	28.6
1.75	8.22	28.8
2.25	8.24	29.2
2.50	8.25	29.5
3.50	8.31	30.0
4.00	8.34	30.4
5.00	8.48	31.0
5.50	8.61	31.6
6.00	8.82	32.2
6.25	8.91	32.7
6.50	8.99	33.0
6.75	9.02	33.5
7.00	9.04	33.9
7.25	9.05	34.6
7.50	9.05	34.6

Average romm temp. 22.3 °C

Vivax "N P" No 19 Type
(3 cells)

Discharge at a constant rate of 5 Amperes.

Time in hours	Volts	Temp C°	Sp. Gr.
0.00	6.85	22.7	1.275
0.50	6.22	22.7	1.275
1.50	6.22	22.4	1.273
2.50	6.21	22.2	1.268
3.50	6.19	22.0	1.260
4.50	6.17	22.0	1.255
5.50	6.16	22.0	1.250
6.50	6.12	22.2	1.243
7.00	6.12	22.2	
8.00	6.10	22.3	
9.00	6.09	22.5	1.225
10.00	6.06	22.5	1.222
11.00	6.03	22.6	1.213
12.00	6.01	22.6	1.208
13.00	5.99	22.7	1.202
14.00	5.97	22.8	1.188
15.00	5.93	22.9	1.185
16.00	5.90	22.9	1.180
17.00	5.88	22.7	1.173
18.00	5.83	22.5	1.160
19.00	5 80	22.1	1.157
20.00	5.76	21.9	1.155
21.00	5.70	21.8	1.152
22.00	5.63	21.9	1.150
22.83	5.52	21.9	1.135

Average room temp 20.5 °C

Vivax "N P" No. 19 Type
(3Cells)

Charge at a constant rate of 15 Amperes.
Run No.3.

Time in hours	Volts	Temp C°	Sp. Gr.
0.00	6.10	22.0	1.135
0.25	6.42	22.2	
0.50	6.43	22.5	
1.00	6.45	23.1	1.135
1.50	6.49	23.5	
1.75	6.51	23.8	
2.25	6.55	24.3	
2.50	6.59	24.7	
3.50	6.67	25.6	1.150
4.00	6.72	26.0	
5.00	6.85	26.6	1.160
5.50	6.97	27.0	
6.00	7.11	27.4	1.175
6.25	7.20	27.7	
6.50	7.31	28.0	
6.75	7.42	28.4	
7.00	7.58	28.8	1.208
7.25	7.72	29.6	
7.50	7.84	30.7	
7.75	7.96	31.9	
8.00	8.02	33.0	1.265
8.25	8.08	34.3	1.275
8.50	8.10	35.4	1.275
8.75	8.10	36.7	1.275

Average room temp 22.3 oC

Edison "B4" Type.
(5 cells)

Discharge at a constant rate of 5 amperes.
Run No. 4.

Time in hours	Volts	Temp.C°
0.00	7.70	25.1
0.25	7.14	25.1
0.50	7.04	25.2
0.75	6.98	25.2
1.75	6.80	25.2
2.75	6.68	25.2
3.75	6.61	25.5
4.75	6.54	25.7
5.75	6.51	26.2
6.75	6.48	27.2
7.75	6.43	27.7
8.75	6.41	28.3
9.75	6.37	28.4
10.75	6.34	28.5
11.75	6.30	29.15
12.75	6.27	29.4
13.75	6.21	30.1
14.75	6.16	30.1
15.75	6.09	30.1
16.75	6.01	30.1
17.75	5.89	30.1
18.58	5.37	30.6

Average room temp. 23°

Edison "B4" Type.
(5 cells)

Charge of a constant rate of 15 amperes.
Run No. 4

Time in hours	Volts	Temp. C°
0.00	7.70	26.0
0.25	8.21	26.7
0.50	8.38	27.2
0.75	8.30	27.6
1.00	8.23	28.0
2.00	8.22	29.0
3.00	8.27	30.0
4.00	8.32	30.9
5.00	8.47	31.8
5.75	8.69	32.7
6.00	8.78	33.0
6.50	8.97	33.9
6.75	9.00	34.3
7.00	9.03	34.8
7.25	9.03	35.1

Average room temp. 22.2 °C

Vivax "N P" No.19 Type
(3 cells)

Discharge at a constant rate of 5 amperes.
Run No. 4

Time in hours	Volts	Temp.C°	Sp. Gr.
0.00	6.88	28.3	1.285
0.25	6.22	28.3	1.283
0.50	6.22	28.1	
0.75	6.23	28.0	1.280
1.75	6.22	27.2	1.275
2.75	6.21	26.2	1.268
3.75	6.19	25.5	
4.75	6.18	25.1	
5.75	6.14	24.8	1.253
6.75	6.13	24.6	1.250
7.75	6.12	24.5	1.240
8.75	6.11	24.5	1.235
9.75	6.09	24.4	1.225
10.75	6.07	24.2	1.220
11.75	6.05	24.15	1.215
12.75	6.03	24.2	1.210
13.75	6.00	24.2	1.203
14.75	5.98	24.3	1.195
15.75	5.95	24.3	1.190
16.75	5.92	24.2	1.180
17.75	5.90	24.0	1.175
18.75	5.87	23.7	1.170
19.75	5.82	23.5	1.160
20.75	5.78	23.4	1.155
21.75	5.72	23.3	1.150
22.75	5.64	23.0	1.135
23.71	5.52	22.9	1.128

Average Room Temp. 23 °C

Vivax "N P" No. 19 Type.
(3 cells)

Charge at a constant rate of 15 amperes.
Run No. 4.

Time in hours	Volts	Temp.C°	Sp.Gr.
0.00	6.08	22.9	1.125
0.25	6.41	23.0	
0.50	6.41	23.1	
0.75	6.41	23.3	
1.00	6.42	23.6	1.130
2.00	6.51	24.6	1.130
3.00	6.59	25.8	1.138
4.00	6.72	26.9	
5.00	6.83	27.8	
5.75	6.97	28.5	1.160
6.00	7.02	28.7	
6.50	7.19	29.2	1.178
6.75	7.30	29.4	
7.00	7.40	29.8	
7.25	7.66	30.3	
7.75	7.87	32.6	1.250
8.25	8.00	34.7	1.265
8.75	8.08	37.6	1.275
9.00	8.11	39.0	
9.25	8.11	40.3	1.280

Average Room Temp. 22.2 °C

Edison "B4" Type
(5 cells)

Discharge at a constant rate of 10 Amperes
Run No. 4.

Time in hours	Volts	Temp. C°.
0.00	7.50	29.2
0.25	6.83	29.4
0.50	6.70	29.7
1.00	6.60	29.9
1.50	6.51	30.0
2.00	6.42	30.2
3.00	6.32	31.0
4.00	6.28	31.4
5.00	6.19	31.8
6.00	6.10	32.2
7.00	5.98	32.8
8.00	5.81	33.5
8.50	5.66	33.8
8.75	5.40	34.0
8.83	5.19	34.2

Average Room Temp. 22.3 °C.

Edison "B4" Type.
(5 cells)

Charge at a constant rate of 15 amperes.
Run No. 5.

Time in hours	Volts	Temp. C°
0.00	7.58	30.8
0.25	8.03	31.3
0.50	8.31	31.6
0.75	8.26	31.8
1.00	8.21	31.9
1.25	8.20	31.7
1.50	8.19	31.6
1.75	8.19	31.5
2.25	8.21	31.3
2.75	8.24	31.0
3.25	8.28	30.7
3.75	8.33	30.7
4.25	8.38	30.8
4.75	8.49	31.0
5.25	8.65	31.3
5.75	8.87	31.7
6.25	9.05	32.7
6.50	9.07	32.9
6.75	9.08	33.2
7.00	9.08	33.5

Average Room Temp. 22 °C.

Vivax "N P" No. 19 Type.
(3 cells)

Discharge at a constant rate of 10 amperes
Run No. 5

Time in hours	Volts	Temp. C°	Sp. Gr.
0.00	6.77	34.1	1.280
0.25	6.18	34.0	
0.50	6.18	33.8	
1.00	6.18	33.3	1.270
1.50	6.16	32.5	
2.00	6.13	31.8	1.258
3.00	6.11	30.6	1.250
4.00	6.07	29.7	1.240
5.00	6.02	28.7	1.230
6.00	6.00	27.7	1.215
7.00	5.92	27.1	1.205
8.00	5.88	26.6	1.183
8.50	5.82	26.3	
9.00	5.78	26.1	1.170
9.30	5.72	25.9	
10.00	5.68	25.8	1.258
10.25	5.62	25.8	
10.50	5.58	25.7	1.150
10.75	5.52	25.7	
11.07	5.46	25.6	1.148

Average Room Temp. 22.3 °C.

Vivax "N P" No. 19 Type.
(3 cells)

Charge at a constant rate of 15 amperes.
Run No. 5.

Time in hours	Volts	Temp. C°	Sp. Gr.
0.00	6.08	25.6	1.148
0.25	6.40	25.7	
0.50	6.42	25.6	
0.75	6.42	25.6	1.138
1.00	6.46	25.6	
1.25	6.48	25.7	
1.50	6.50	25.8	1.150
1.75	6.53	25.9	
2.25	6.58	25.9	
2.75	6.62	25 9	
3.25	6.68	26.0	
3.75	6.74	26.1	1.160
4.25	6.80	26.2	1.165
4.75	6.87	26.5	1.175
5.25	6.98	36.8	1.177
5.75	7.09	27.1	1.180
6.25	7.40	27.7	
6.50	7.55	27.8	
6.75	7.73	28.2	1.235
7.00	7.91	29.5	
7.25	8.03	30.5	1.265
7.50	8.09	31.9	
7.75	8.15	33.4	1.280
8.00	8.18	34.6	1.280
8.25	8.19	35.9	1.280
8.50	8.19	37.3	1.280

Average Room Temp. 22 °C

Edison "B4" Type.
(5 cells)

Discharge at a constant rate of 10 amperes.
Run No. 6.

Time in Hours	Volts	Temp. C°
0.00	7.38	31.4
0.25	6.86	31.5
0.50	6.76	31.7
1.00	6.62	31.8
1.50	6.53	32.1
2.00	6.48	32.4
3.00	6.38	32.9
4.00	6.30	83.3
5.00	6.22	33.8
6.00	6.13	34.1
7.00	6.01	34.7
8.00	5.85	35.1
8.92	5.19	35.8

Average Room Temp. 22 °C.

Edison "B4" Type.
(5 cells)

Charge at a constant rate of 15 amperes
Run No. 6.

Time in hours	Volts	Temp. C°
0.00	7.64	32.3
0.50	8.29	32.9
1.00	8.19	33.2
1.50	8.18	33.1
2.00	8.18	33.0
2.50	8.21	33.0
3.00	8.21	33.0
3.50	8.25	33.0
4.50	8.37	33.4
5.00	8.45	33.7
5.50	8.62	33.8
5.75	8.82	33.5
6.00	8.95	33.7
6.25	8.99	34.0
6.50	9.02	34.3
6.75	9.03	34.7
7.00	9.03	35.0

Average Room Temp. 22.7 °C

Vivax "N P" No. 19 Type.
(3 cells)

Discharge at a constant rate of 10 amperes.
Run No. 6.

Time in hours	Volts	Temp. C°	Sp. Gr.
0.00	6.65	37.1	1.280
0.25	6.23	36.8	
0.50	6.22	36.5	
1.00	6.20	35.5	1.278
1.50	6.18	34.6	
2.00	6.16	33.9	1.265
3.00	6.11	32.6	1.250
4.00	6.08	31.5	1.235
5.00	6.03	30.6	1.225
6.00	6.00	29.7	1.215
7.00	5.94	28.9	1.205
8.00	5.88	28.2	1.200
9.00	5.81	27.6	1.175
10.00	5.70	27.0	1.165
10.25	5.68	27.0	
10.50	5.63	26.9	
10.75	5.58	26.9	
11.00	5.52	26.8	1.150
11.27	5.46	26.8	1.145

Average Room Temp. 22°C.

Vivax "N P" No. 19 Type.
(3 cells)

Charge at a constante rate of 15 amperes.
Run No. 6.

Time in hours	Volts	Temp.C°	Sp. Gr.
0.00	6.30	26.8	1.145
0.50	6.41	26.9	
1.00	6.44	27.1	1.150
1.50	6.52	27.5	
2.00	6.55	27.7	
2.50	6.59	28.1	1.150
3.00	6.63	28.0	
3.50	6.68	28.3	1.155
4.50	6.79	29.0	1.165
5.00	6.87	29.3	
5.50	6.98	29.5	1.180
5.75	7.08	29.3	
6.00	7.21	29.2	
6.25	7.33	29.3	
6.50	7.56	29.7	1.210
6.75	7.75	30.4	1.235
7.00	7.89	31.4	1.255
7.25	7.99	32.4	1.265
7.50	8.08	33.9	1.278
7.75	8.12	35.5	1.285
8.00	8.15	36.7	1.285
8.25	8.16	38.1	1.285
8.50	8.16	39.4	1.285

Average Room Temp. 22.7 °C.

Edison"B4" Type.
(5 cells)

Discharge at a constant rate of 15 amperes.
Run No. 7.

Time in hours	Volts	Temp. C°
0.00	7.31	18.7
0.25	6.52	19.5
1.00	6.20	21.6
1.50	6.12	22.7
2.00	6.08	23.8
2.50	6.01	25.2
3.00	5.97	26.2
3.50	5.91	27.5
4.00	5.82	28.8
4.50	5.72	30.1
5.00	5.58	31.5
5.25	5.51	32.1
5.50	5.34	32.8
5.72	5.00	33.7

Average Room Temp. 20 °C.

Edison "B4" Type
(5 cells)

Charge at a constant rate of 15 amperes.
Run No. 7.

Time in hours	Volts	Temp. C°
0.00	7.45	33.0
0.25	7.82	33.5
0.50	8.21	33.6
0.75	8.26	33.7
1.00	8.21	33.8
2.00	8.17	33.3
2.50	8.17	33.1
3.00	8.20	32.9
3.50	8.24	32.7
4.00	8.29	32.6
4.50	8.37	32.7
5.00	8.43	32.9
5.50	8.58	33.2
6.00	8.83	33.8
6.25	8.97	34.2
6.50	9.01	34.8
6.75	9.02	35.4
7.00	9.02	35.8

Average Room Temp. 21.8 °C

Vivax "N P" No. 19 Type
(3 cells)

Discharge at a constant rate of 15 amperes.
Run No. 7.

Time in hours	Volts	Temp.C°	Sp. Gr.
0.00	6.70	21.4	1.275
0.25	6.07	21.7	
1.00	6.04	21.9	1.270
1.50	6.02	21.9	
2.00	6.01	21.8	1.255
2.50	5.98	21.6	
3.00	5.94	21.6	1.240
3.50	5.90	21.5	
4.00	5.87	21.5	1.215
4.50	5.80	21.6	
5.00	5.73	21.6	
5.00	5.73	21.7	1.200
5.25	5.70	21.8	
5.50	5.66	21.9	
5.75	5.61	22.0	
6.00	5.56	22.2	1.180
6.25	5.49	22.4	
6.50	5.40	22.6	1.168

Average Room Temp. 20 °C

Vivax "N P" No. 19 Type
(3 cells)

Charge at a constant rate of 15 amperes.
Run No. 7.

Time in hours	Volts	Temp. C°	Sp. Gr.
0.00	6.08	22.6	1.168
0.25	6.38	22.9	
0.50	6.43	23.0	
0.75	6.46	23.1	
1.00	6.49	23.4	1.170
2.00	6.58	24.1	1.175
2.50	6.62	24.4	
3.00	6.69	24.8	1.177
3.50	6.75	25.1	
4.00	6.80	25.3	1.180
4.50	6.90	25.8	
5.00	7.00	26.1	1.190
5.50	7.18	26.6	
6.00	7.62	27.8	1.215
6.25	7.87	28.5	
6.50	8.01	29.9	
6.75	8.11	31.4	1.275
7.00	8.16	33.0	1.278
7.25	8.18	34.5	1.280
7.50	8.18	35.6	1.280

Average Room Temp. 21.8 °C

Edison "B$_4$" Type.
(5 cells)

Discharge at a constant rate of 15 amperes
Run No. 8.

Time in hours	Volts	Temp. C°
0.00	7.42	26.0
0.25	6.59	26.7
0.50	6.48	27.3
0.75	6.39	27.8
1.00	6.32	28.5
1.25	6.26	29.0
1.50	6.22	29.5
1.75	6.19	30.3
2.00	6.17	30.4
2.25	6.13	31.1
2.50	6.11	31.6
2.75	6.09	32.2
3.00	6.07	32.5
3.50	6.00	33.7
4.00	5.91	34.5
4.50	5.81	35.5
4.75	5.77	36.1
5.00	5.69	36.7
5.25	5.61	37.3
5.50	5.50	37.9
5.75	5.21	38.5
5.82	5.00	38.8

Average Room Temp. 23.2 °C

Edison "B4" Type
(5 cells)

Charge at a constant rate of 15 amperes
Run No. 8

Time in hours	Volts	Temp. C°
0.00	7.38	27.8
0.25	7.83	38.2
0.50	8.11	38.2
0.75	8.19	38.2
1.00	8.15	38.2
2.25	8.08	37.5
2.75	8.10	37.2
3.25	8.13	36.9
3.75	8.18	36.6
4.25	8.23	36.2
4.75	8.31	35.8
5.25	8.42	35.8
5.75	8.59	35.9
6.25	8.91	36.0
6.50	8.98	36.1
6.75	9.01	36.3
7.00	9.02	36.4
7.25	9.02	36.6

Average Room Temp. 22.5 °C

Vivax "N P" No. 19 Type
(3 cells)

Discharge at a constant rate of 15 amperes
Run No. 8.

Time in hours	Volts	Temp. C°	SP. Gr.
0.00	6.72	28.6	1.285
0.25	6.11	28.9	
0.50	6.10	29.0	
0.75	6.10	28.9	
1.00	6.09	28.8	1.263
1.25	6.08	28.6	
1.50	6.06	28.6	
1.75	6.03	28.4	
2.00	6.03	28.4	1.250
2.25	6.01	28.2	
2.50	5.99	28.1	
2.75	5.98	28.1	
3.00	5.96	28.0	1.233
3.50	5.92	27.9	
4.00	5.87	27.7	
4.50	5.82	27.6	1.205
5.00	5.76	27.5	1.180
5.25	5.72	27.5	
5.50	5.68	27.5	
5.75	5.63	27.6	
6.00	5.59	27.6	1.170
6.50	5.45	27.7	
6.58	5.40	27.8	1.160

Average Room Temp. 23.2 °C

Vivax "N P" No. 19 Type.
(3 cells)

Charge at a constant rate of 15 amperes
Run No. 8.

Time in hours	Volts	Temp. C°	Sp. Gr.
0.00	6.05	27.8	1.160
0.25	6.34	28.0	
0.50	6.40	28.1	
0.75	6.42	28.1	
1.00	6.44	28.2	1.160
2.25	6.56	29.0	1.168
2.75	6.60	29.2	
3.25	6.66	29.3	
3.75	6.71	29.4	1.178
4.25	6.78	29.6	
4.75	6.86	29.6	1.188
5.25	6.98	29.6	
5.75	7.20	29.8	1.203
6.25	7.71	30.5	1.230
6.50	7.92	31.4	
6.75	8.07	32.7	1.275
7.00	8.14	34.2	1.280
7.25	8.18	35.6	1.280
7.50	8.19	37.0	1.280
7.75	8.19	39.3	1.280

Average Room Temp. 22.5 °C

Edison "B4" Type.
(5 cells)

Discharge at a constant rate of 20 amperes.
Run No. 9.

Time in hours	Volts	Temp. C°
0.00	7.05	26.5
0.25	6.42	27.3
0.50	6.27	28.2
0.75	6.18	28.9
1.00	6.11	29.6
1.25	6.08	30.2
1.50	6.03	31.2
1.75	5.98	32.0
2.00	5.95	32.3
2.25	5.91	33.2
2.50	5.88	34.0
2.75	5.81	34.7
3.00	5.75	35.5
3.25	5.68	36.0
3.50	5.60	36.5
3.75	5.51	37.6
4.00	5.38	38.8
4.25	5.13	40.0
4.33	4.82	40.5

Average Room Temp. 20.3 °C

Edison "B4" Type
(5 cells)

Charge at a constant rate of 15 amperes
Run No. 9

Time in hours	Volts	Temp.C°
0.00	7.28	40.3
0.25	7.65	40.5
0.50	8.02	40.3
0.75	8.15	40.1
1.00	8.10	39.9
1.50	8.09	39.4
1.75	8.09	39.1
2.00	8.09	38.8
2.25	8.09	38.7
2.50	8.10	38.5
2.75	8.10	38.2
4.00	8.19	37.5
4.50	8.22	37.3
5.00	8.32	37.0
5.50	8.43	36.8
6.00	8.70	36.8
6.25	8.88	36.9
6.50	8.96	37.0
6.75	9.00	37.2
7.00	9.00	37.4

Average Room Temp. 20.5 °C

Vivax "N P" No. 19 Type
(3 cells)

Discharge at a constant rate of 20 amperes.

Time in hours	Volts	Temp. C°	Sp. Gr.
0.00	6.60	29.7	1.280
0.25	6.03	29.9	
0.50	6.03	29.8	1.275
0.75	6.02	29.6	
1.00	6.01	29.4	1.268
1.25	6.00	29.2	
1.50	5.99	29.0	1.250
1.75	5.95	28.9	
2.00	5.92	28.8	1.243
2.25	5.90	28.6	
2.50	5.88	28.4	1.225
2.75	5.83	28.3	
3.00	5.81	28.2	1.215
3.25	5.77	28.2	
3.50	5.72	28.2	1.203
3.75	5.68	28.2	
4.00	5.61	28.2	1.183
4.25	5.53	28.3	
4.50	5.47	28.4	1.175
4.75	5 34	28.7	1.170

Average Room Temp. 20.3 °C

Vivax "N P" No. 19 Type
(3 cells)

Charge at a constant rate of 15 amperes
Run No. 9.

Time in hours	Volts	Temp.C°	Sp. Gr.
0.00	6.08	28.7	1.170
0.25	6.36	28.8	
0.50	6.40	28.8	
0.75	6.40	28.9	1.165
1.00	6.46	29.0	
1.50	6.50	29.1	1.175
1.75	6.52	29.3	
2.00	6.54	29.4	
2.25	6.58	29.4	1.175
2.50	6.60	29.6	
2.75	6.63	29.7	
4.00	6.77	30.4	1.185
4.50	6.83	30.4	
5.00	6.96	30.5	1.195
5.50	7.18	30.6	
6.00	7.78	31.2	1.235
6.25	8.00	32.6	1.260
6.50	8.11	34.0	1.277
6.75	8.18	35.5	1.280
7.00	8.19	36.8	1.280
7.25	8.19	38.0	1.280

Average Room Temp. 20.5 °C

Edison "B4" Type
(5 cells)

Discharge at a constant rate of 20 amperes
Run No. 10.

Time in hours	Volts	Temp. C°
0.00	7.23	26.7
0.25	6.35	27.5
0.50	6.22	68.6
0.75	6.14	29.5
1.00	6.09	30.2
1.25	6.05	31.0
1.50	6.01	31.8
1.75	5.97	32.7
2.00	5.95	33.3
2.25	5.90	34.2
2.50	5.83	35.1
2.50	5.83	35.1
2.75	5.79	36.0
3.00	5.73	36.4
3.25	5.63	37.4
3.50	5.55	38.3
4.00	5.32	39.9
4.25	4.92	41.0
4.28	4.82	41.1

Average Room Temp. 22.1 °C

Edison "B4" Type
(5 cells)

Charge at a constant rate of 15 amperes
Run No. 10

Time in hours	Volts	Temp. C°
0.00	7.27	40.8
0.25	7.67	40.9
0.50	8.10	40.6
0.75	8.19	40.5
1.00	8.13	40.4
1.25	8.10	40.2
1.75	8.07	39.6
2.00	8.08	39.3
2.25	8.09	39.1
2.50	8.09	38.9
2.75	8.10	38.7
3.00	8.11	38.5
3.25	8.13	38.3
3.50	8.15	37.9
3.75	8.18	37.9
4.00	8.19	37.8
5.00	8.37	37.2
5.50	8.48	37.0
5.75	8.61	37.0
6.00	8.78	36.9
6.50	8.98	37.2
6.75	8.99	37.3
7.00	9.00	37.5
7.25	9.00	38.2

Average Room Temp. 21.5 °C

Vivax "N P" No. 19 Type.
(3 cells)

Discharge at a constant rate of 20 amperes.
Run No. 10

Time in hours	Volts	Temp. C°	Sp. Gr.
0.00	6.57	29.2	1.280
0.25	6.05	29.3	
0.50	6.02	29.4	
0.75	6.01	29.3	1.265
1.00	6.00	29.1	
1.25	5.98	29.1	
1.50	5.96	29.1	1.250
1.75	5.94	29.1	
2.00	5.91	29.0	1.234
2.25	5.89	28.9	
2.25	5.89	28.9	
2.50	5.85	28.9	1.220
2.75	5.83	28.9	
3.00	5.79	28.9	1.210
3.25	5.75	28.8	
3.50	5.69	28.8	1.185
4.00	5.60	29.0	1.183
4.25	5.52	29.0	
4.50	5.42	29.2	1.170
4.75	5.34	29.3	1.168

Average Room Temp. 22.1 °C

Vivax "N P" No. 19 Type
(3 cells)

Charge at a constant rate of 15 amperes.
Run No. 10.

Time in Hours	Volts	Temp:C°	Sp. Gr.
0.00	6.08	29.3	1.168
0.25	6.36	29.5	
0.50	6.38	29.5	
1.00	6.43	29.6	1.165
1.25	6.47	29.7	
1.75	6.51	30.0	1.175
2.00	6.52	30.2	
2.25	6.58	30.3	1.175
2.50	6.59	30.4	
2.75	6.62	30.6	1.180
3.00	6.64	30.7	
3.25	6.67	30.9	1.185
3.50	6.70	31.0	
3.75	6.73	31.0	1.185
4.00	6.76	31.1	
5.00	6.99	31.1	1.200
5.50	7.21	30.8	
5.75	7.50	31.1	
6.00	7.83	31.8	1.240
6.50	8.13	34.7	1.275
6.75	8.18	36.1	1.278
7.00	8.20	37.5	1.280
7.25	8.21	38.9	1.280
7.50	8.21	41.0	1.280

Average Room Temp. 21.5 °C

Edison "B4" Type.
(5 cells)

Discharge at a constant rate of 25 amperes.
Run No. 11

Time in Hours	Volts	Temp. C°
0.00	7.08	22.8
0.25	6.18	24.2
0.50	6.00	25.1
0.75	5.91	27.4
1.00	5.85	28.7
1.25	5.81	29.9
1.50	5.77	31.2
1.75	5.72	32.4
2.00	5.67	33.6
2.25	5.58	35.0
2.50	5.48	36.3
2.75	5.38	37.6
3.00	5.25	38.9
3.25	5.04	40.0
3.45	4.63	41.7

Average Room Temp 20 °C

Edison "B_4" Type.
(5 cells)

Charge at a constant rate of 15 amperes.
Run No. 11

Time in Hours	Volts	Temp. C°
0.00	7.17	41.8
0.25	7.57	41.5
0.50	7.98	41.3
0.75	8.12	41.0
1.00	8.15	40.7
1.50	8.10	40.0
2.00	8.10	39.0
2.50	8.11	38.4
3.00	8.13	37.8
3.50	8.18	37.3
4.25	8.25	36.5
4.75	8.32	36.2
5.00	8.38	36.0
5.50	8.49	35.9
6.00	8.71	35.9
6.25	8.86	36.0
6.50	8.96	36.2
6.75	9.00	36.5
7.00	9.00	36.8

Average Room Temp. 20.5 °C.

Vivax "N P" No. 19 Type.
(3 cells)

Discharge at a constant rate of 25 amperes.
Run No. 11

Time in hours	Volts	Temp.C°	Sp. Gr.
0.00	6.40	26.4	1.275
0.25	5.99	27.o	
0.50	5.98	27.1	1.270
0.75	5.97	27.1	
1.00	5.93	27.2	1.255
1.25	5.91	27.2	
1.50	5.88	27.2	1.240
1.75	5.83	27.2	
2.00	5.80	27.3	1.227
2.25	5.73	27.3	
2.50	5.68	27.4	1.210
2.75	5.62	27.5	
3.00	5.55	27.6	1.193
3.25	5.44	27.7	
3.50	5.31	28.0	
3.55	5.28	28.1	1.175

Average Room Temp. 20 °C

Vivax "N P" No. 19 Type.
(3 cells)

Charge at a constant rate of 15 amperes.
Run No. 11

Time in hours	Volts	Temp.C°	Sp. Gr.
0.00	6.07	28.1	1.175
0.25	6.38	28.2	
0.50	6.41	28.2	
0.75	6.42	28.0	
1.00	6.46	27.9	1.170
1.50	6.51	28.0	
2.00	6.56	28.0	
2.50	6.63	28.1	
3.00	6.70	28.2	1.175
3.50	6.75	28.3	
4.25	6.89	28.3	1.195
4.75	7.01	28.4	
5.00	7.19	28.5	1.200
5.50	7.77	29.2	
6.00	8.12	31.8	1.265
6.25	8.21	33.4	1.278
6.50	8.22	34.8	1.278
6.75	8.23	36.2	1.278
7.00	8.23	37.4	1.278

Average Room Temp. 20.5 °C

Edison "B4" Type.
(5 cells)

Discharge at a constant rate of 25 amperes.
Run No. 12.

Time in hours	Volts	Temp.C°
0.00	7.02	25.3
0.25	6.16	26.8
0.50	6.02	28.1
0.75	5.94	29.1
1.00	5.87	30.5
1.25	5.85	31.6
1.50	5.80	32.5
2.00	5.68	35.5
2.25	5.60	36.4
2.50	5.50	38.0
2.75	5.40	38.9
3.00	5.27	40.2
3.25	5.03	41.7
3.42	4.63	42.7

Average Room Temp. 22.5 °C

Edison "B4" Type.
(5 cells)

Charge at a constant rate of 15 amperes
Run No. 12.

Time in hours	Volts	Temp.C°
0.00	7.12	43.0
0.25	7.57	43.3
0.50	7.97	43.0
0.75	8.10	42.7
1.00	8.11	42.4
1.75	8.07	41.2
2.00	8.07	40.9
2.25	8.08	40.4
2.50	8.09	40.1
3.00	8.10	39.6
3.50	8.13	39.2
4.00	8.17	38.9
4.25	8.21	38.5
5.50	8.42	37.9
6.00	8.69	37.9
6.25	8.88	38.0
6.50	8.94	38.2
6.75	8.97	38.5
7.00	8.97	38.7

Average Room Temp. 21.5 °C

Vivax "N P" No. 19 Type.
(3 cells)

Discharge at a constant rate of 25 amperes
Run No. 12.

Time in hours	Volts	Temp.C°	Sp. Gr.
0.00	6.45	27.5	1.278
0.25	5.99	27.9	
0.50	5.98	28.0	
0.75	5.98	28.0	
1.00	5.95	28.0	1.250
1.25	5.91	28.1	
1.50	5.87	28.1	
1.75	5.83	28.1	
2.00	5.78	28.2	
2.25	5.72	28.3	
2.50	5.69	28.4	1.200
2.75	5.62	28.5	
3.00	5.55	28.7	1.195
3.25	5.43	28.9	
3.50	5.28	29.2	1.178

Average Room Temp. 22.5 °C

Vivax "N P" No. 19 Type
(3 cells)

Charge at a constant rate of 15 amperes
Run No. 12.

Time in hours	Volts	Temp.C°	Sp.Gr.
0.00	6.07	29.2	1.178
0.25	6.37	29.3	
0.50	6.42	29.3	
0.75	6.45	29.2	
1.00	6.48	29.2	1.175
1.75	6.58	29.6	
2.00	6.61	29.9	
2.25	6.64	30.2	1.175
2.50	6.70	30.3	
3.00	6.76	30.6	
3.50	6.84	31.0	
4.00	6.92	31.2	1.185
4.25	7.00	31.5	
5.50	7.72	32.1	1.215
6.00	8.20	34.4	1.258
6.25	8.28	35.7	1.275
6.50	8.31	37.2	1.278
6.75	8.32	38.7	1.278
7.00	8.32	39.9	1.278

Average Room Temp. 21.5 °C

Edison "B4" Type.
(5 cells)

Discharge at a constant rate of 30 Amperes
Run No. 13.

Time in hours	Volts	Temp.C°
0.00	7.00	27.6
0.25	6.01	27.5
0.50	5.88	30.8
0.75	5.81	32.6
1.00	5.75	34.2
1.25	5.69	35.8
1.50	5.62	37.6
1.75	5.53	39.1
2.00	5.41	40.7
2.25	5.28	42.5
2.50	5.10	44.3
2.75	4.72	46.4
2.83	4.44	47.5

Average Room Temp. 21.5 °C

Edison "B4" Type.
(5 cells)

Charge at a constant rate of 15 amperes.
Run No. 13.

Time in hours	Volts	Temp. C°
0.00	7.03	47.5
0.25	7.56	47.1
0.50	7.84	46.8
0.75	8.04	46.3
1.00	8.08	45.8
1.25	8.06	45.3
1.50	8.03	44.7
2.00	8.02	43.8
2.50	8.03	42.8
3.00	8.06	42.0
3.50	8.10	41.3
4.00	8.14	40.7
4.50	8.19	40.2
5.00	8.28	39.7
5.50	8.39	39.6
6.25	8.73	39.6
6.50	8.87	39.7
6.75	8.91	40.0
7.00	8.91	40.2

Average Room Temp. 22.5 °C

Vivax "N P" No. 19 Type
(3 cells)

Discharge at a constant rate of 30 amperes
Run No. 13.

Time in hours	Volts	Temp.C°	Sp. Gr.
0.00	6.30	29.8	1.280
0.25	5.98	30.3	
0.50	5.93	30.3	1.265
0.75	5.91	30.4	
1.00	5.89	30.5	1.250
1.25	5.81	30.5	
1.50	5.77	30.5	1.230
1.75	5.71	30.6	
2.00	5.63	30.7	1.215
2.25	5.55	30.9	
2.50	5.43	31.1	1.195
2.75	5.29	31.5	
2.82	5.22	31.7	1.185

Average Room Temp. 21.5 °C

Vivax "N P" No. 19 Type.
(3 cells)

Charge at a constant rate of 15 amperes.
Run No. 13.

Time in Hours	Volts	Temp.C°	Sp. Gr.
0.00	6.17	31.7	1.185
0.25	6.38	31.7	
0.50	6.41	31.4	
0.75	6.42	31.2	
1.00	6.46	31.1	1.180
1.25	6.48	31.1	
1.50	6.51	31.1	1.183
2.00	6.57	31.2	
2.50	6.61	31.2	1.190
3.00	6.68	31.3	
3.50	6.73	31.4	1.195
4.00	6.81	31.4	
4.50	6.92	31.5	1.200
5.00	7.19	31.9	
5.50	7.76	32.7	1.230
6.25	8.19	37.6	1.278
6.50	8.20	39.1	1.280
6.75	8.20	40.4	1.280

Average Room Temp. 22.5 °C

Edison "B4" Type.
(5 cells)

Discharge at a constant rate of 30 amperes.
Run No. 14.

Time in hours	Volts	Temp.C°
0.00	7.04	26.5
0.25	6.00	28.5
0.50	5.88	30.0
1.00	5.73	33.3
1.25	5.69	35.2
1.50	5.62	36.7
1.75	5.53	38.0
2.00	5.41	40.0
2.25	5.29	41.6
2.50	5.12	43.4
2.75	4.81	45.4
2.85	4.44	46.3

Average Room Temp. 23 °C

Edison "B_4" Type.
(5 cells)

Charge at a constant rate of 15 amperes.
Run No. 14.

Time in hours	Volts	Temp.C°
0.00	6.98	46.9
0.25	7.46	47.1
0.50	7.79	46.6
0.75	8.05	46.0
1.00	8.10	45.6
1.25	8.08	45.0
1.50	8.05	44.4
1.75	8.03	44.0
2.00	8.03	43.4
2.50	8.06	42.4
3.00	8.09	41.5
3.50	8.13	40.5
4.00	8.17	39.6
4.50	8.23	39.4
5.00	8.30	39.0
6.00	8.65	38.9
6.25	8.87	38.9
6.50	8.91	39.0
6.75	8.94	39.1
7.00	8.97	39.2
7.25	8.97	39.4

Average Room Temp. 21 °C

Vivax "N P" No. 19 Type.
(3 Cells)

Discharge at a constant rate of 30 amperes
Run No. 14.

Time in hours	Volts	Temp.C°	Sp.Gr.
0.00	6.53	29.2	1.278
0.25	5.97	29.8	
0.50	5.93	29.8	1.265
1.00	5.88	29.8	1.245
1.25	5.81	29.8	
1.50	5.78	29.9	1.230
1.75	5.71	30.0	
2.00	5.63	30.2	1.210
2.25	5.54	30.4	
2.50	5.43	30.7	1.190
2.75	5.26	31.0	
2.77	5.22	31.1	1.180

Average Room Temp. 23°C

Vivax "N P" No.13 Type.
(3 cells)

Charge at a constant rate of 15 amperes.
Run No.14.

Time in hours	Volts	Temp.C°	Sp.Gr.
0.00	6.17	31.1	1.178
0.25	6.39	31.1	
0.50	6.41	30.9	
0.75	6.44	30.7	1.175
1.00	6.48	30.6	
1.25	6.50	30.6	
1.50	6.52	30.5	1.175
1.75	6.55	30.5	
2.00	6.58	30.5	1.180
2.50	6.64	30.5	
3.00	6.69	30.5	1.180
3.50	6.76	30.5	
4.00	6.90	30.4	1.200
4.50	7.60	30.4	
5.00	7.87	30.9	1.215
6.00	8.21	36.2	1.270
6.25	8.22	37.9	1.278
6.50	8.22	39.0	1.278
6.75	8.21	40.0	1.278

Average Room Temp. 21 °C

EDISON "B_4" TYPE

Results in Terms of One Cell

Run	Amp. Rate		Hours On		Amp.-Hrs.		Mean Volts		Watt-Hrs.		% Efficiency	
Number	Dis.	Chg.	Dis.	Chg.	Dis.	Chg.	Dis.	Chg.	Dis.	Chg.	A.H.	W.H.
3	5	15	18.50	7.50	92.5	112.5	1.272	1.695	117.8	190.7	82.1	61.7
4	5	15	18.58	7.25	92.9	108.8	1.286	1.688	119.6	183.8	85.4	65.2
5	10	15	8.83	7.00	88.3	105.0	1.244	1.691	109.8	177.7	84.1	61.8
6	10	15	8.92	7.00	89.2	105.0	1.250	1.682	111.6	176.5	84.9	63.1
7	15	15	5.72	7.00	85.8	105.0	1.190	1.675	102.2	176.0	81.7	58.1
8	15	15	5.82	7.25	87.3	108.8	1.208	1.665	105.3	181.2	80.2	58.2
9	20	15	4.33	7.00	86.6	105.0	1.179	1.653	102.2	173.8	82.6	58.8
10	20	15	4.28	7.25	85.6	108.8	1.173	1.663	100.5	181.0	78.7	55.5
11	25	15	3.45	7.00	86.2	105.0	1.136	1.658	98.2	174.1	82.2	56.2
12	25	15	3.42	7.00	85.5	105.0	1.141	1.650	97.6	173.2	81.4	56.4
13	30	15	2.83	7.00	84.9	105.0	1.118	1.640	95.0	172.1	80.8	55.1
14	30	15	2.85	7.25	85.5	108.8	1.118	1.650	95.8	179.7	78.6	53.3

EDISON "B_4" TYPE

Results in Terms of One Cell

Average Values

Run	Amp. Rate		Hours On		Amp.-Hrs.		Mean Volts		Watt-Hrs.		%Efficiency	
Number	Dis.	Chg.	Dis.	Chg.	Dis.	Chg.	Dis.	Chg.	Dis.	Chg.	A.H.	W.H.
3-4	5	15	18.54	7.375	92.70	110.7	1.279	1.692	118.7	187.3	83.75	63.45
5-6	10	15	8.875	7.000	88.75	105.0	1.247	1.687	110.7	177.1	84.50	62.45
7-8	15	15	5.770	7.125	86.55	106.9	1.199	1.670	103.8	178.6	80.95	58.15
9-10	20	15	4.305	7.125	86.10	106.9	1.176	1.658	101.4	177.4	80.65	57.15
11-12	25	15	3.435	7.000	85.85	105.0	1.139	1.654	97.9	173.7	81.80	56.30
13-14	30	15	2.840	7.125	85.20	106.9	1.118	1.645	95.4	175.9	79.70	54.20

VIVAX "NP" NO. 19 TYPE

Results in Terms of One Cell

Run	Amp. Rate		Hours On		Amp-hrs.		Mean Volts		Watt-hrs.		% Efficiency	
Number	Dis.	Chg.	Dis.	Chg.	Dis.	Chg.	Dis.	Chg.	Dis.	Chg.	A.H.	W.H.
3	5	15	22.83	8.75	114.15	131.3	2.003	2.329	228.7	306.1	86.9	74.8
4	5	15	23.71	9.25	118.55	138.8	2.010	2.333	238.3	323.0	85.4	73.6
5	10	15	11.07	8.50	110.7	127.5	1.987	2.347	220.0	299.3	86.7	73.5
6	10	15	11.27	8.50	112.7	127.5	1.993	2.340	224.0	298.0	88.4	75.2
7	15	15	6.50	7.50	97.5	112.6	1.956	2.337	190.5	262.5	86.6	72.6
8	15	15	6.58	7.75	98.8	116.3	1.964	2.327	194.0	270.5	84.8	71.7
9	20	15	4.75	7.25	95.0	108.8	1.946	2.318	184.6	252.0	87.3	73.4
10	20	15	4.75	7.50	95.0	112.5	1.941	2.336	184.5	262.1	84.5	70.2
11	25	15	3.55	7.00	88.8	105.0	1.930	2.340	171.5	245.7	84.6	69.8
12	25	15	3.50	7.00	87.5	105.0	1.931	2.363	169.1	246.3	83.4	68.0
13	30	15	2.82	6.75	84.6	101.3	1.916	2.324	162.1	236.0	83.4	68.7
14	30	15	2.77	6.75	83.1	101.3	1.918	2.359	159.4	239.2	82.1	66.5

VIVAX "NP" NO. 19 TYPE

Results in Terms of One Cell

Average Values

Run	Amp. Rate		Hours On		Amp.-hrs.		Mean Volts		Watt-hrs.		% Efficiency	
Number	Dis.	Chg.	Dis.	Chg.	Dis.	Chg.	Dis.	Chg.	Dis.	Chg.	A.H.	W.H.
3-4	5	15	23.27	9.00	116.35	135.05	2.007	2.331	233.50	314.6	86.15	74.20
5-6	10	15	11.17	8.50	111.70	127.5	1.990	2.344	222.0	298.7	87.55	74.35
7-8	15	15	6.54	7.675	98.15	114.5	1.960	2.332	192.3	266.5	85.70	72.15
9-10	20	15	4.75	7.375	95.00	110.65	1.9435	2.327	184.6	257.1	85.90	71.80
11-12	25	15	3.525	7.00	88.15	105.0	1.9305	2.3515	170.3	246.0	84.00	68.90
13-14	30	15	2.795	6.75	83.85	101.3	1.917	2.3412	160.8	237.6	82.75	67.60

Watt-hour Output per Pound of Complete Cell.

Weight in Pounds

Edison - 6.95 Vivax - 18.4

Discharge Rate in Amperes.	Output in watt-hours per pound	
	Edison	Vivax
5	17.08	12.64
10	15.92	12.06
15	14.93	10.45
20	14 57	10.02
25	14.08	9.26
30	13.73	8.74

Watt-hour Output per Cubic Foot of cell.

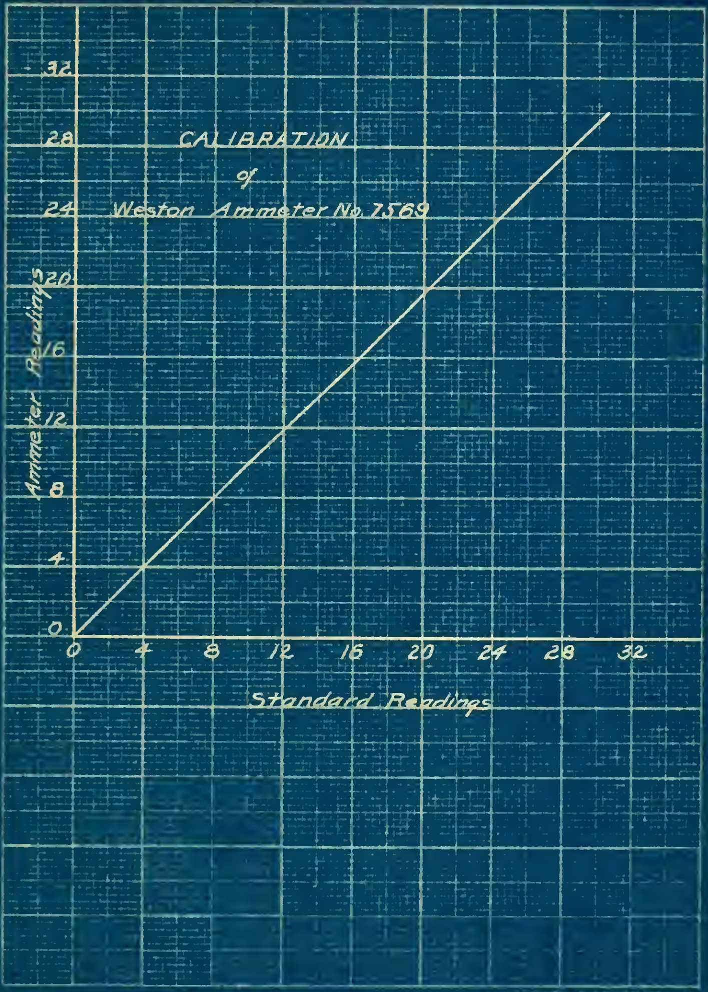
Volume in Cubic Feet.

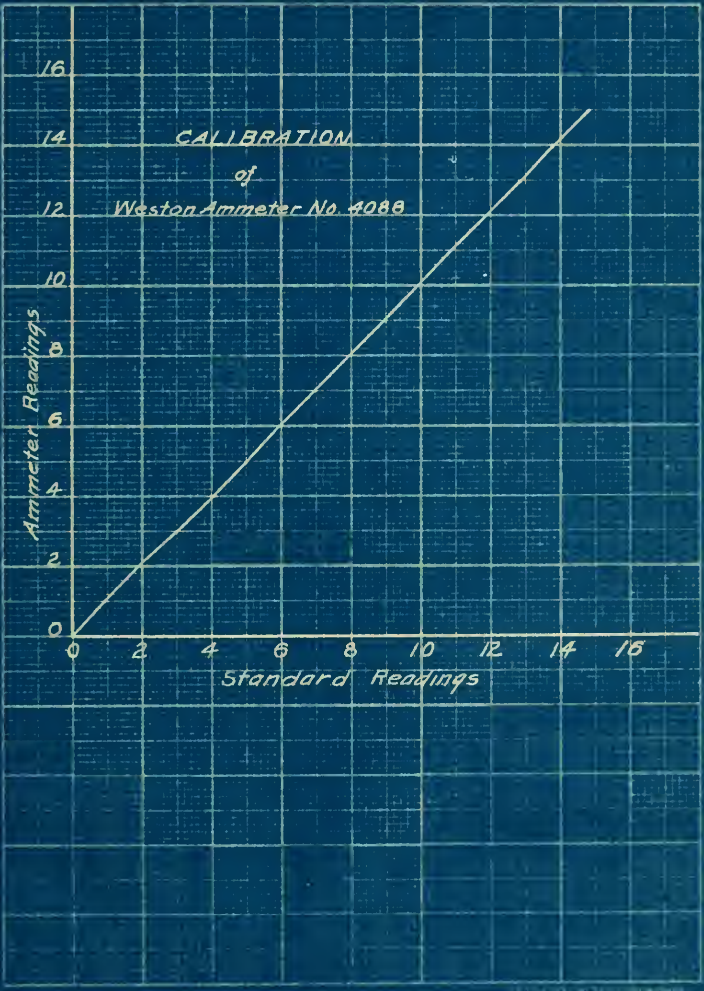
Edison - 0.0504

Vivax - 0.1156

Discharge Rate in Amperes	Output in Watt-hours per Cu.ft Edison	Vivax
5	2357	2022
10	2197	1920
15	2061	1664
20	2014	1598
25	1943	1473
30	1893	1391

CURVES OF TESTS.


CALIBRATION
of
Weston Ammeter No. 7569
Ammeter Readings
0
4
8
12
16
20
24
28
32
Standard Readings
0
4
8
12
16
20
24
28
32


CALIBRATION
of
Weston Ammeter No. 4088
Ammeter Readings
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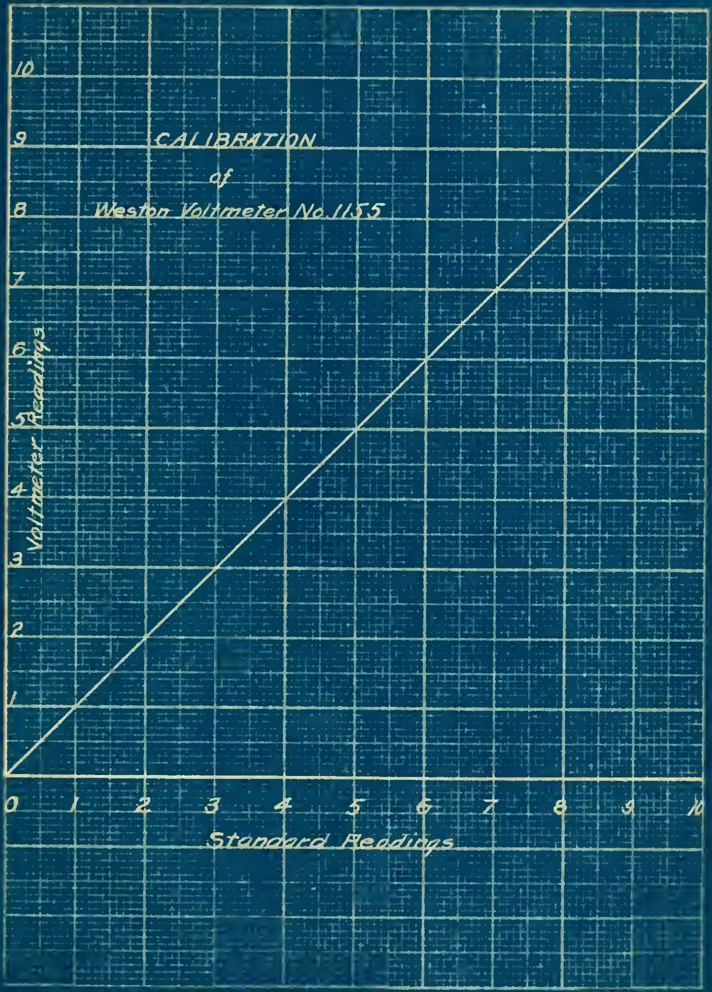
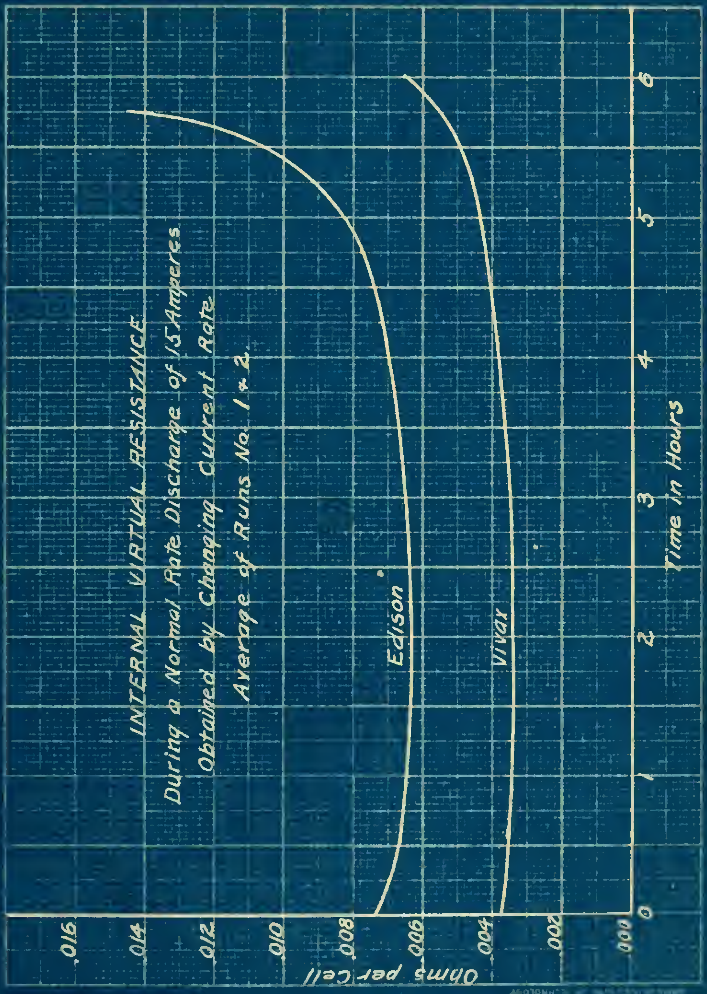
6
8
10
12
14
16
Standard Readings
0
2
4
6
8
10
12
14
16


CALIBRATION
of
Weston Voltmeter No. 1155
Voltmeter Readings
Standard Readings
0
1
2
3
4
5
6
7
8
9
10

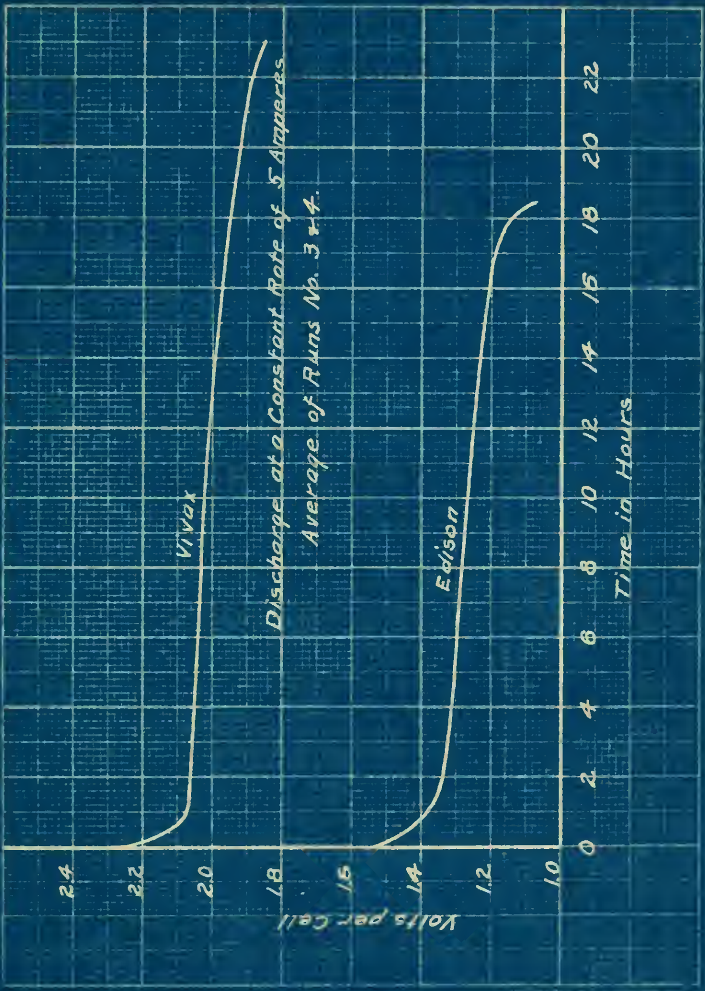


INTERNAL VIRTUAL RESISTANCE

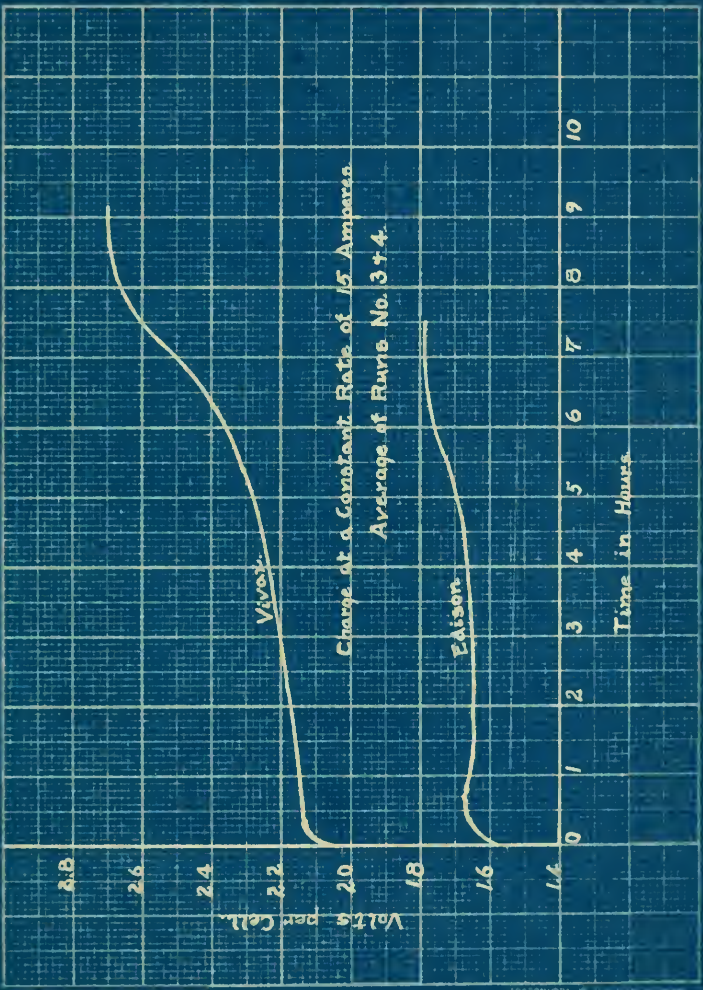
During a Normal Rate Discharge of 15 Amperes

Obtained by Changing Current Rate

Average of Runs No. 1 & 2.

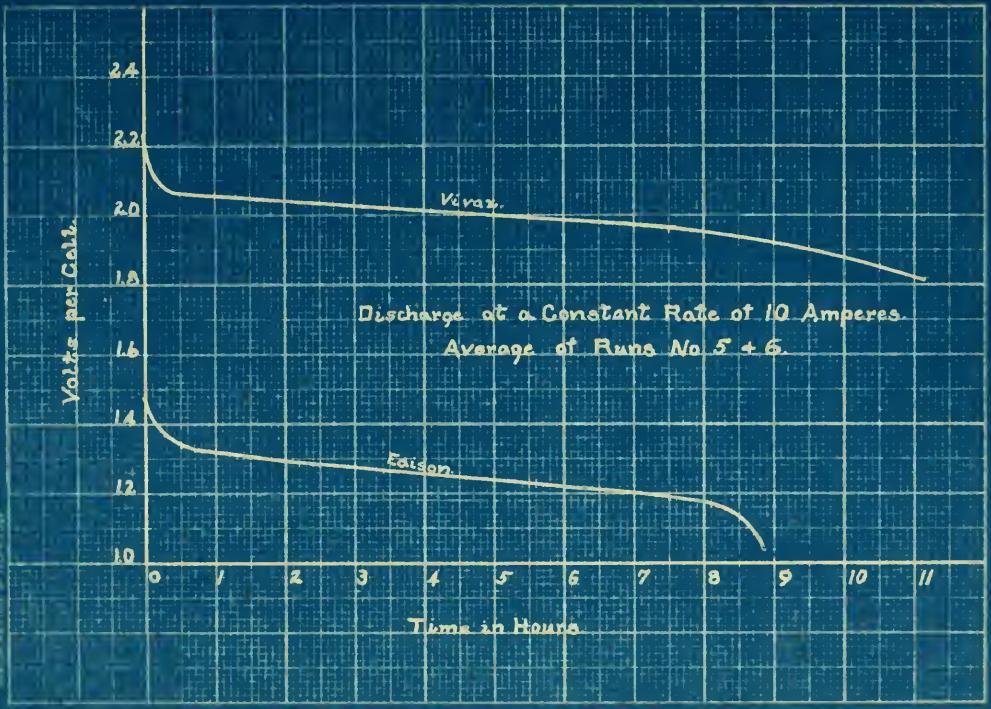


Discharge at a Constant Rate of 5 Amperes.
Average of Runs No. 3 & 4.

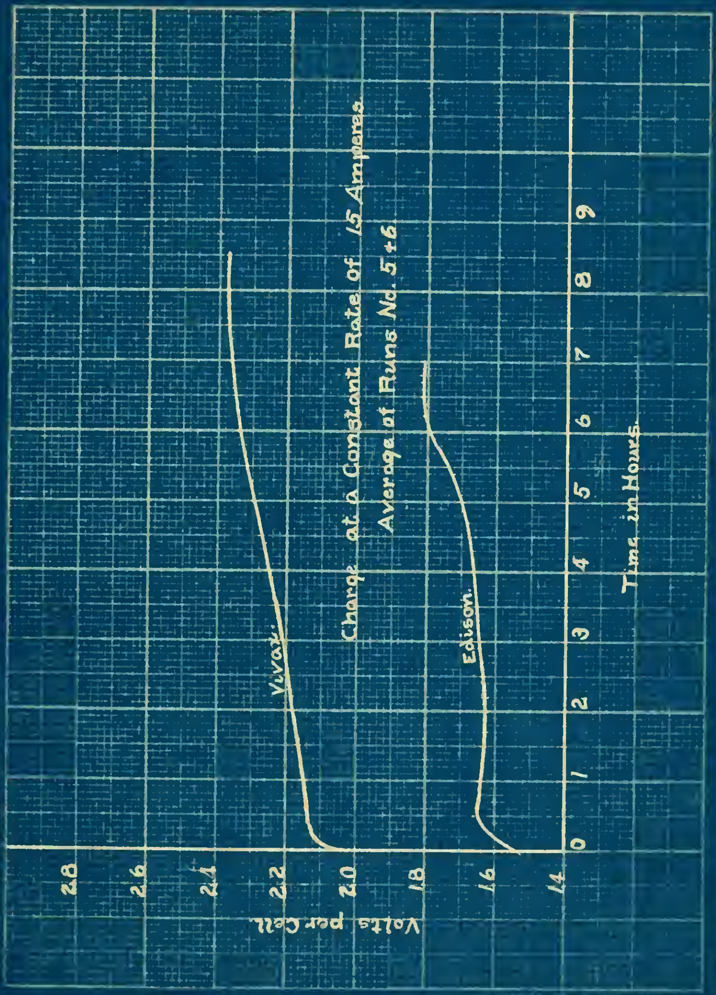


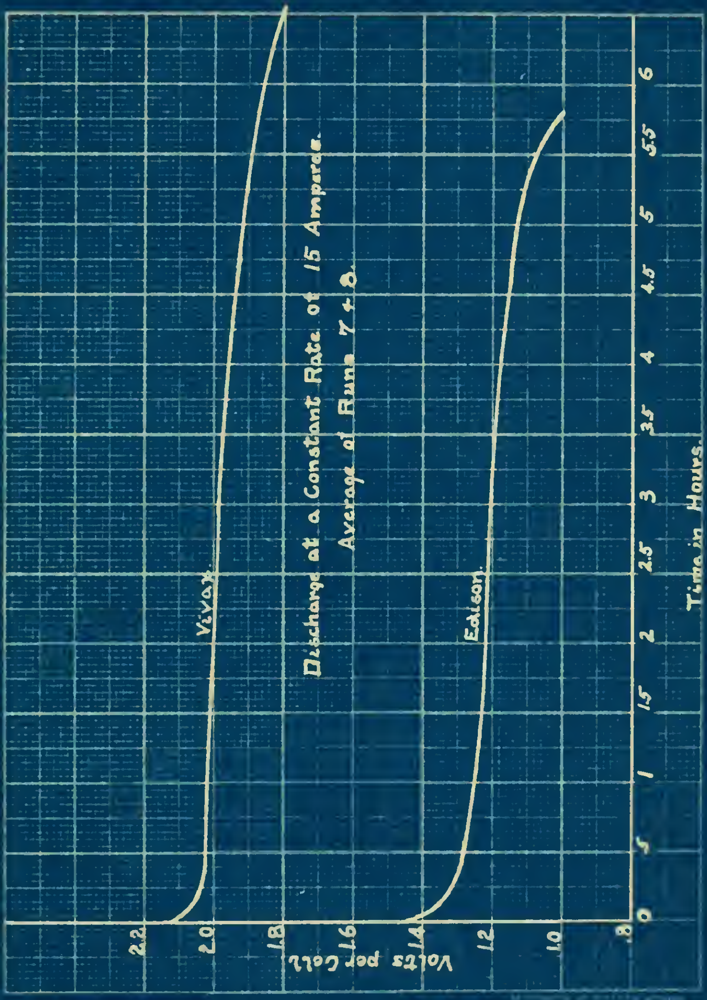
Charge at a Constant Rate of 15 Amperes.

Average of Runs No. 3+4.



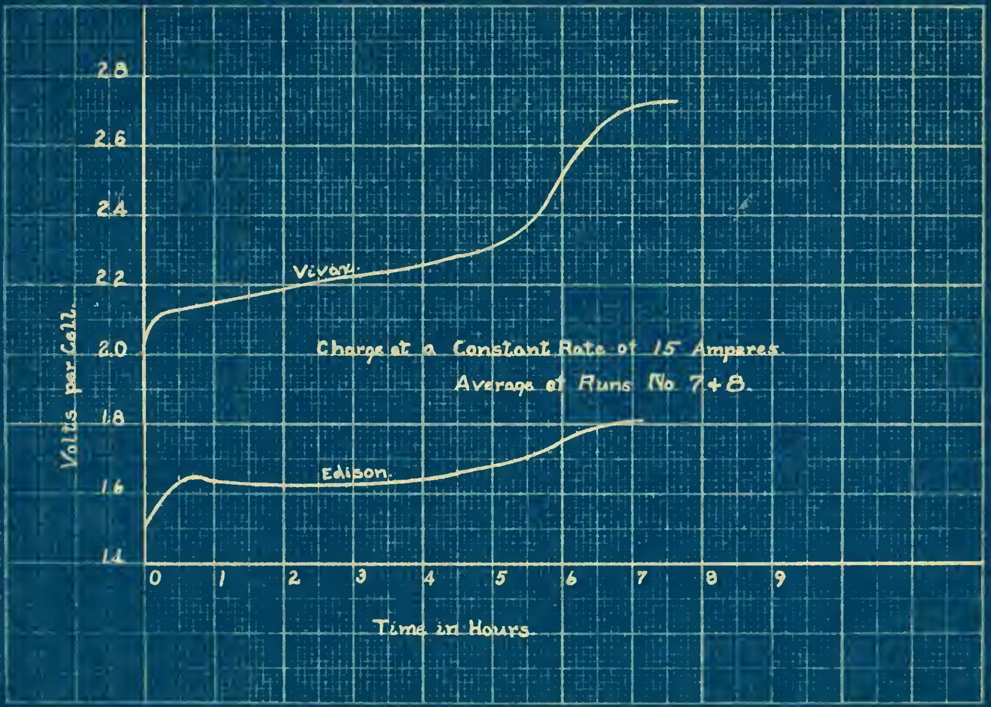
Discharge at a Constant Rate of 10 Amperes.
Average of Runs No 5 + 6.

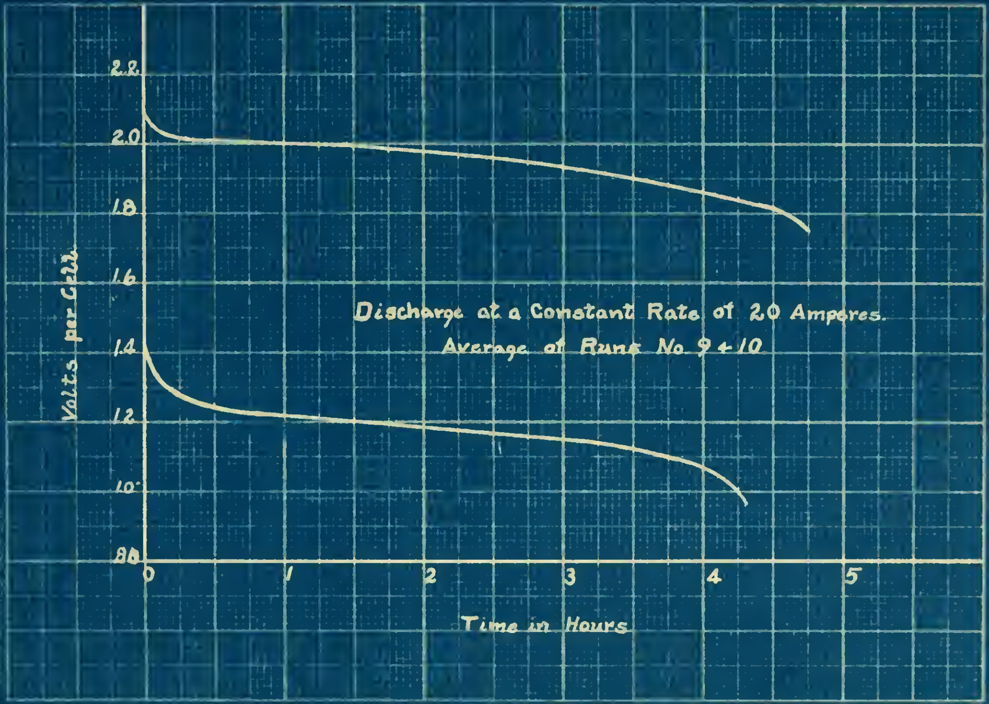

Charge at a Constant Rate of 15 Amperes.
Average of Runs No. 5 + 6
Vivax.
Edison.
Time in Hours.
Volts per Cell.
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
0
1
2
3
4
5
6
7
8
9



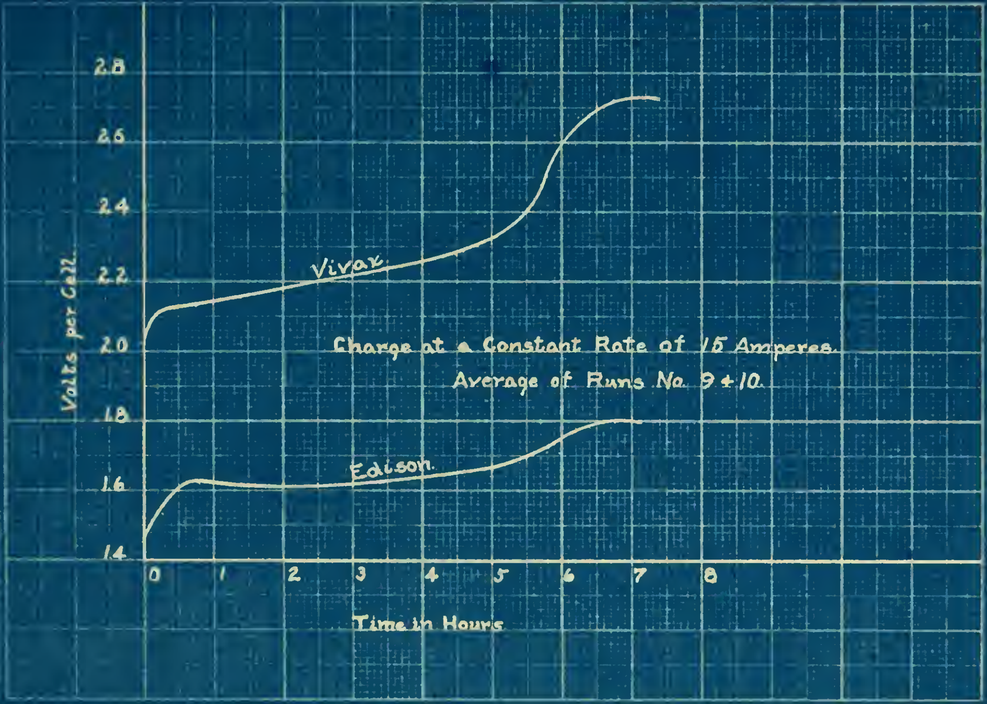
Discharge at a Constant Rate of 15 Amperes.

Average of Runs 7 + 8.


Charge at a Constant Rate of 15 Amperes.
Average of Runs No 7 + 8.
Vivax.
Edison.
Volts per Cell.
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
0
1
2
3
4
5
6
7
8
9
Time in Hours.

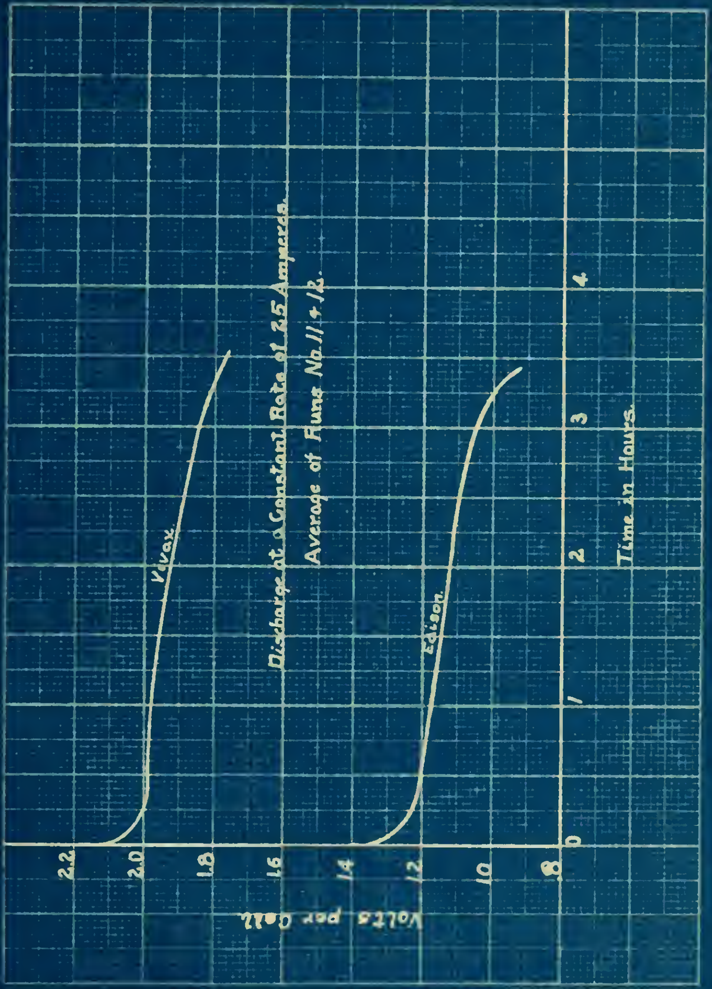


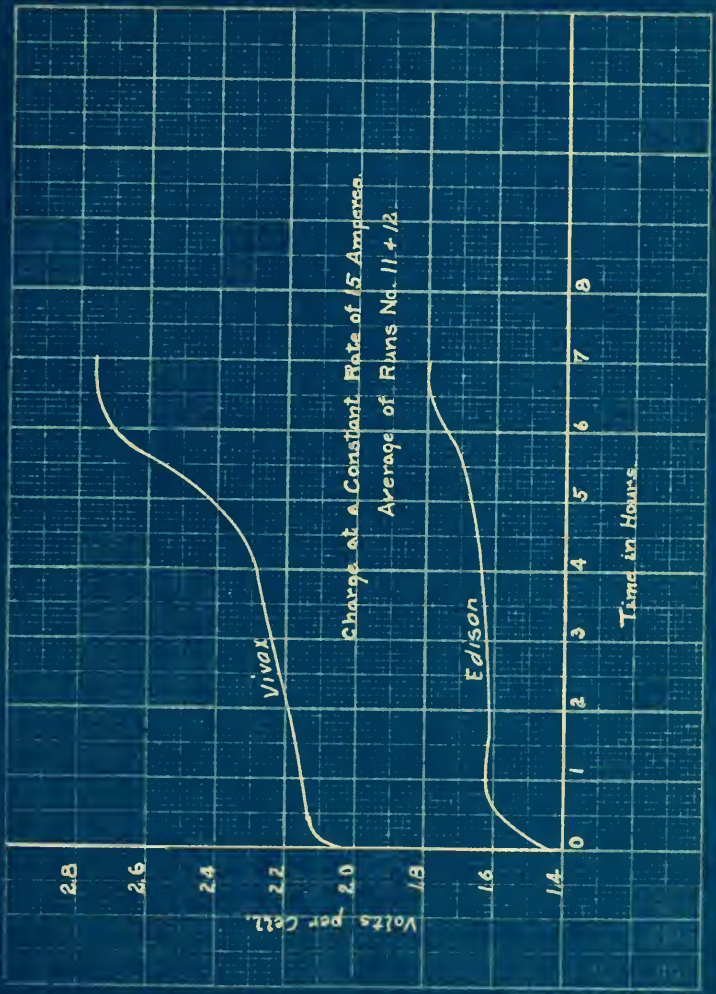
Discharge at a Constant Rate of 2.0 Amperes.
Average of Runs No 9 + 10

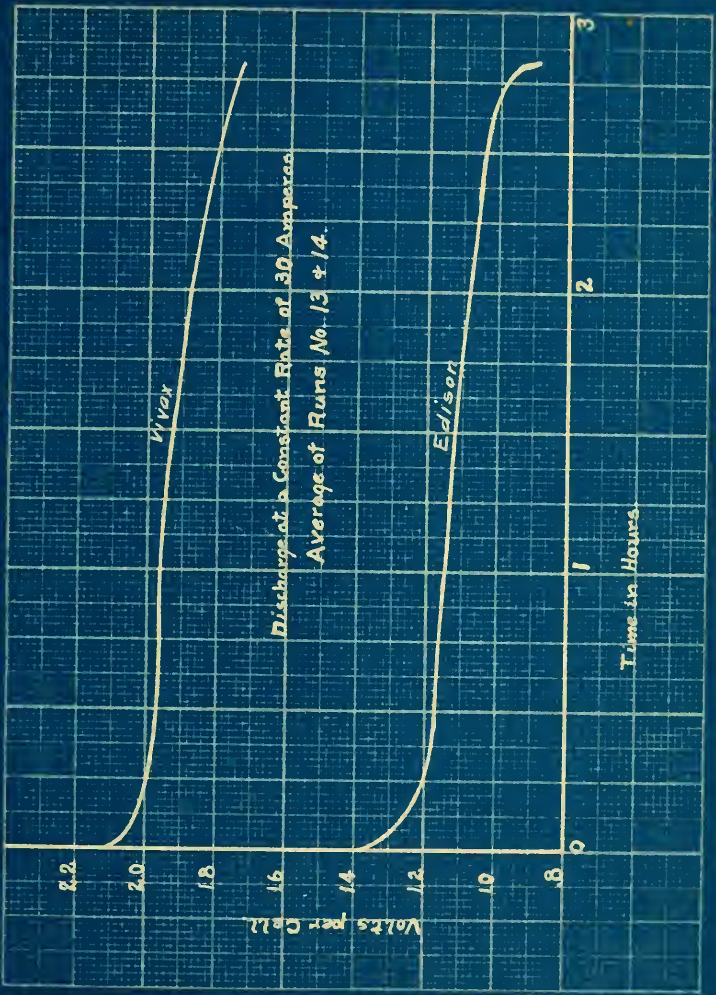


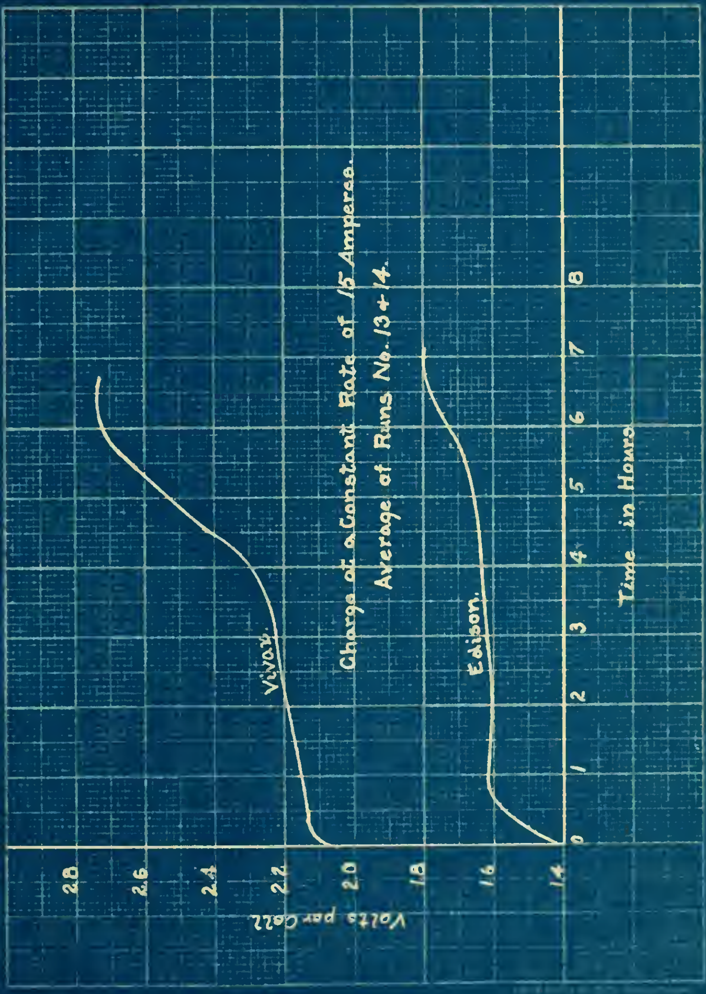
Charge at a Constant Rate of 15 Amperes.

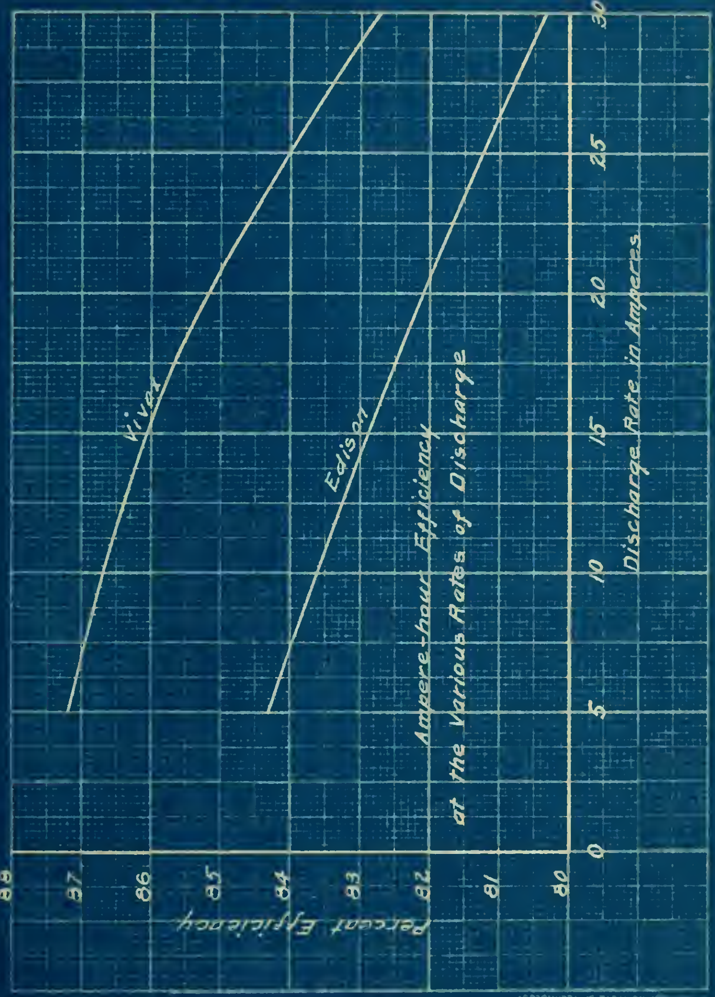
Average of Runs No. 9 + 10.


Discharge at a Constant Rate of 2.5 Amperes.
Average of Runs No. 11 + 12.
Vivax.
Edison.
Time in Hours.
0
1
2
3
4
Volts per Cell
2.2
2.0
1.8
1.6
1.4
1.2
1.0
.8

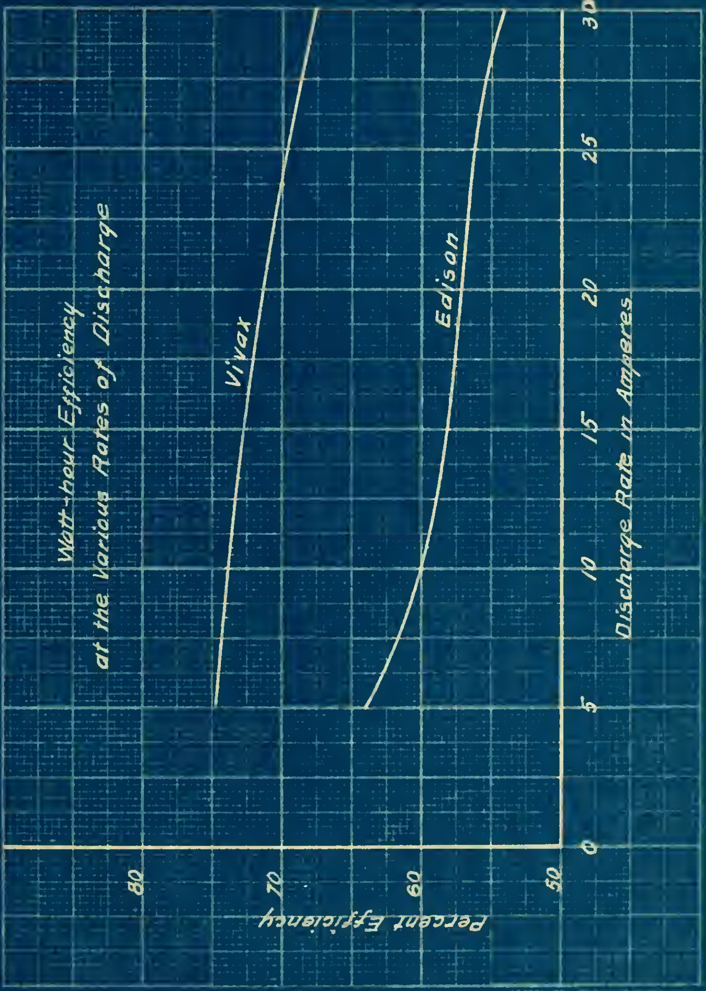

Charge at a Constant Rate of 15 Amperes.
Average of Runs No. 11 + 12.
Vivax
Edison
Volts per Cell.
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
Time in Hours
0
1
2
3
4
5
6
7
8

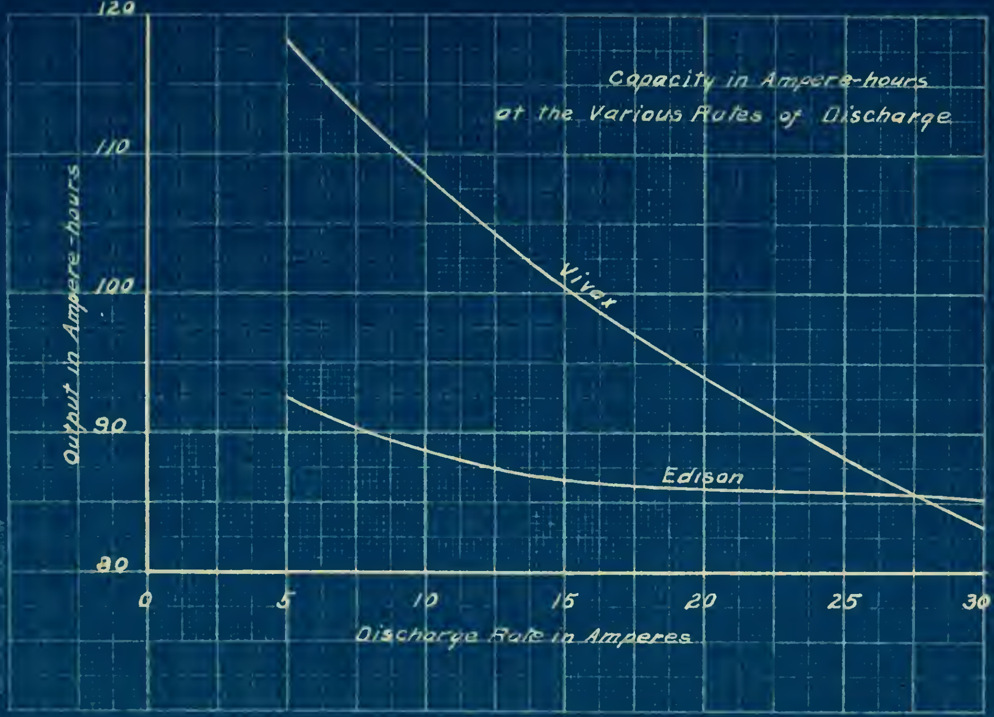

Discharge at a Constant Rate of 30 Amperes
Average of Runs No. 13 + 14.
Vivox
Edison
Volts per Cell
2.2
2.0
1.8
1.6
1.4
1.2
1.0
.8
Time in Hours
0
1
2
3

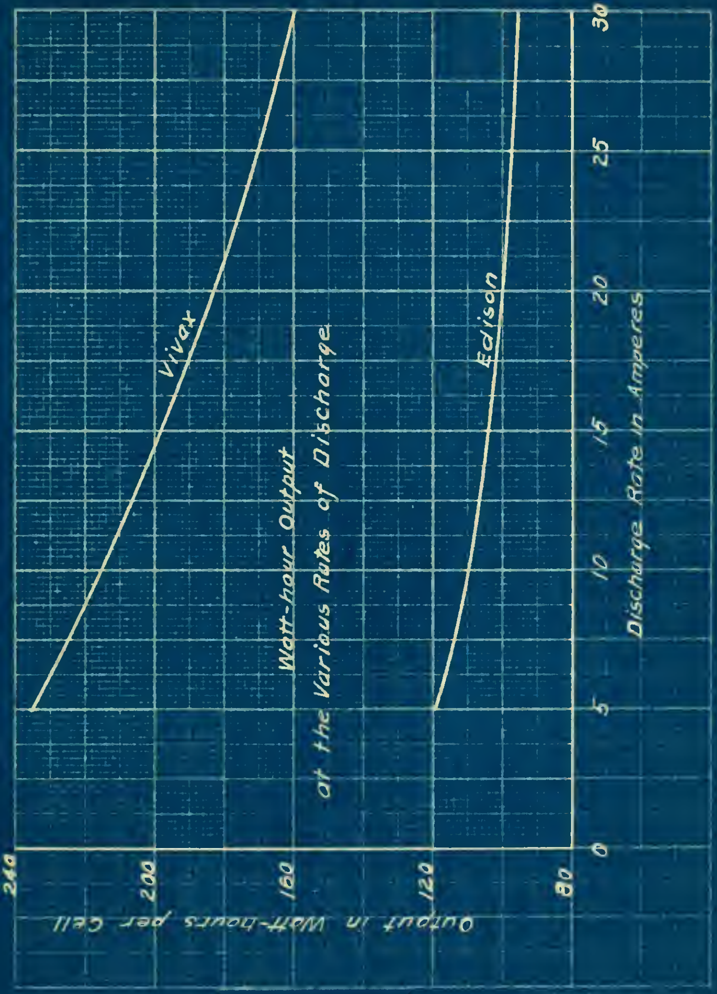

Charge at a Constant Rate of 15 Amperes.
Average of Runs No. 13 + 14.
Vivax.
Edison.
Time in Hours
0
1
2
3
4
5
6
7
8
Volts per Cell
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8



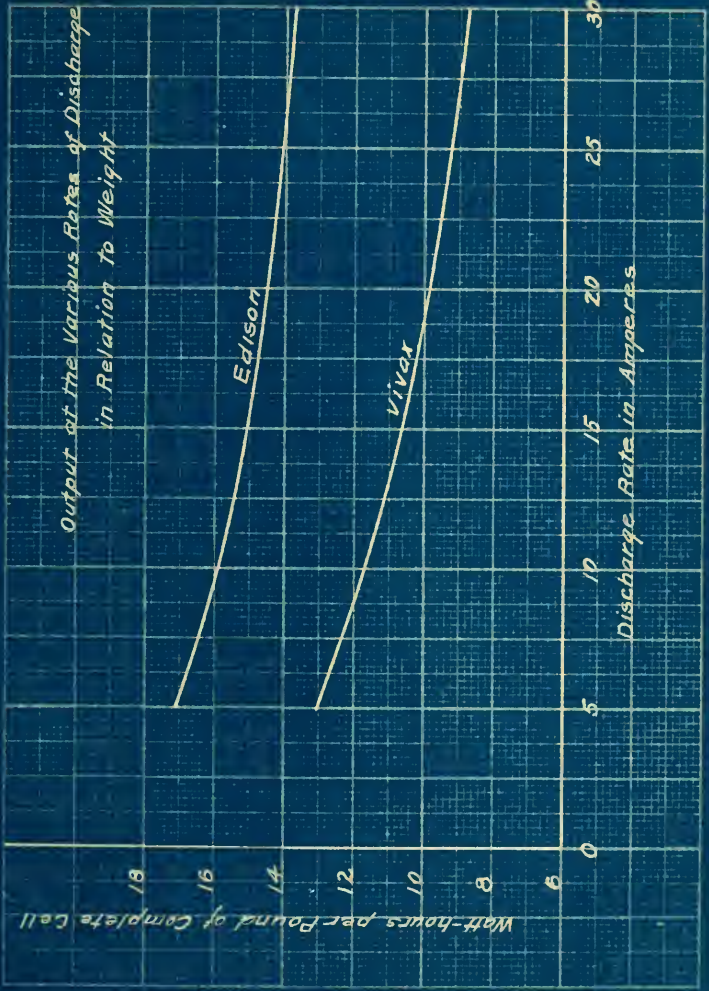
Ampere-hour Efficiency at the Various Rates of Discharge


Watt-hour Efficiency
at the Various Rates of Discharge
Vivax
Edison
Discharge Rate in Amperes
0
5
10
15
20
25
30
Percent Efficiency
50
60
70
80

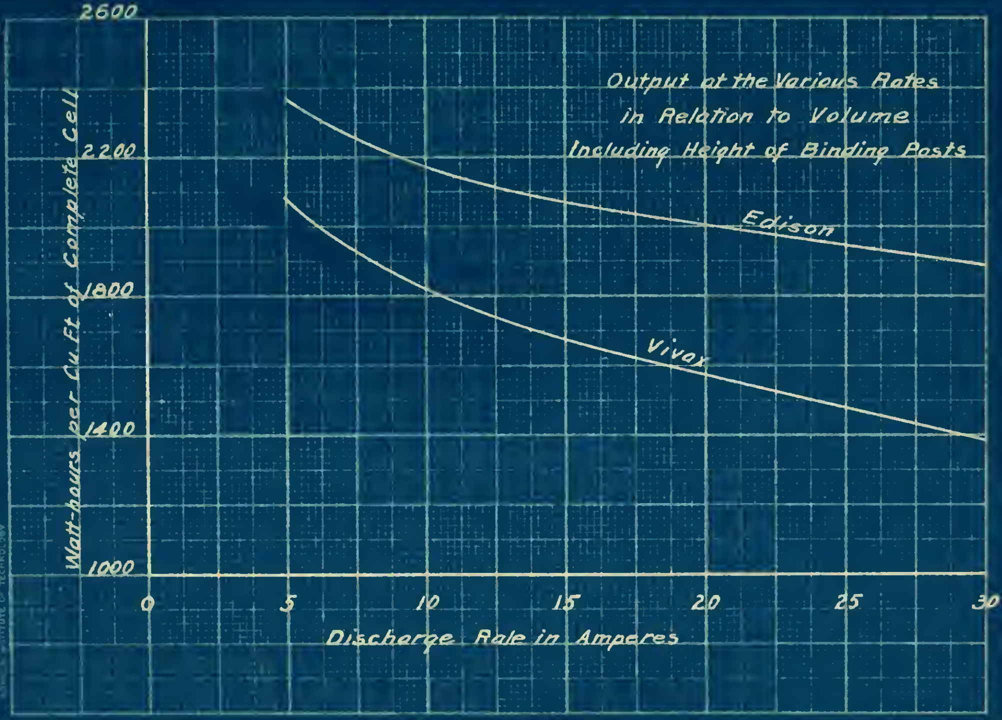

Capacity in Ampere-hours
at the Various Rates of Discharge
Vivax
Edison
Output in Ampere-hours
120
110
100
90
80
0
5
10
15
20
25
30
Discharge Rate in Amperes



Watt-hour Output at the Various Rates of Discharge

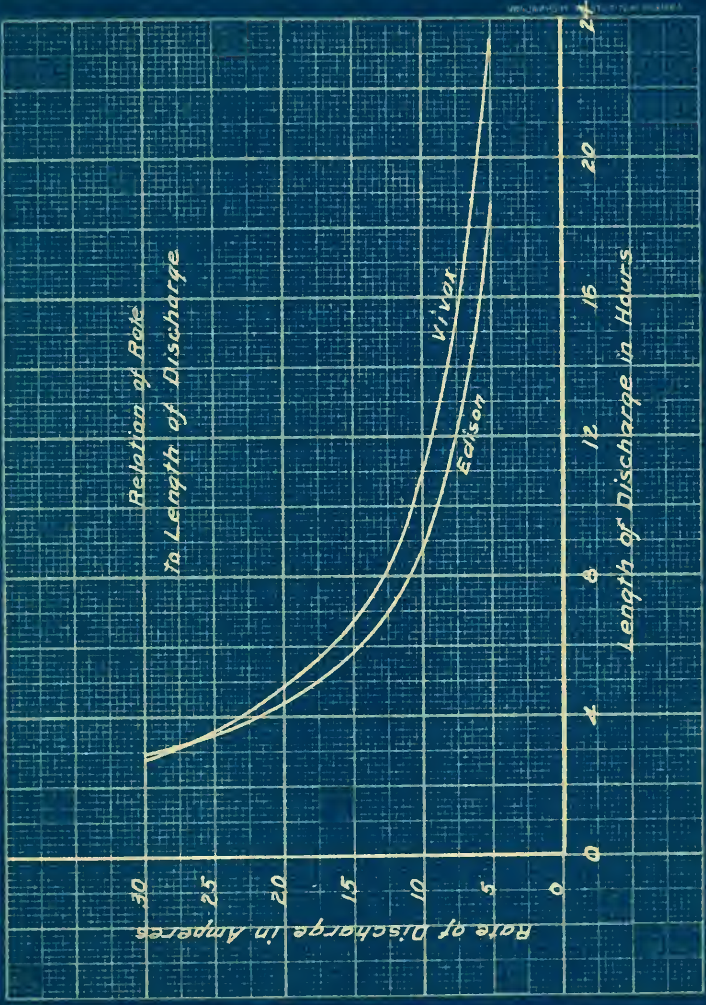


Output at the Various Rates of Discharge in Relation to Weight

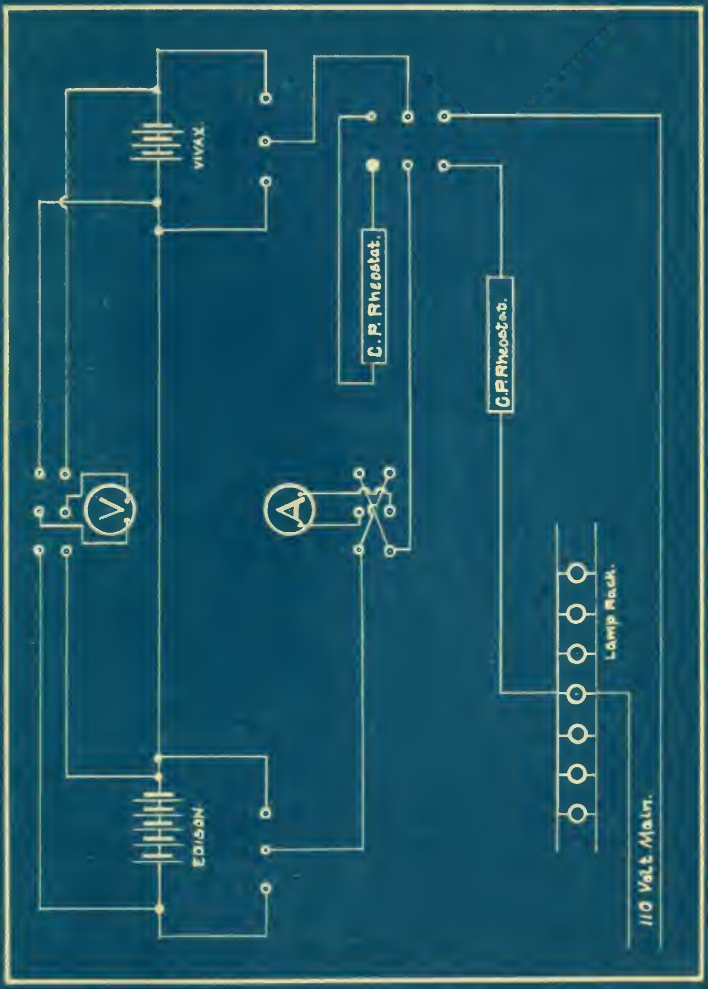


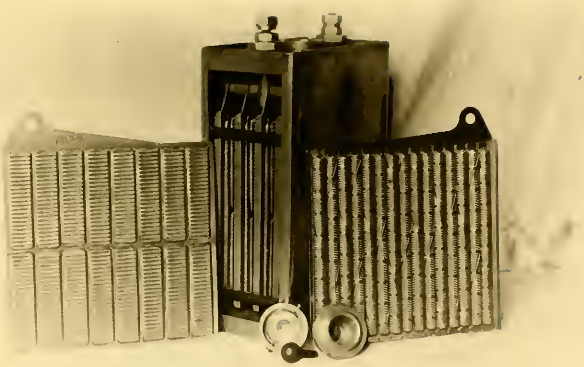
Output at the Various Rates in Relation to Volume Including Height of Binding Posts

INSTITUTE OF TECHNOLOGY


Relation of Rate
to Length of Discharge
Vivox
Edison
Length of Discharge in Hours
0
4
8
12
16
20
24
Rate of Discharge in Amperes
0
5
10
15
20
25
30

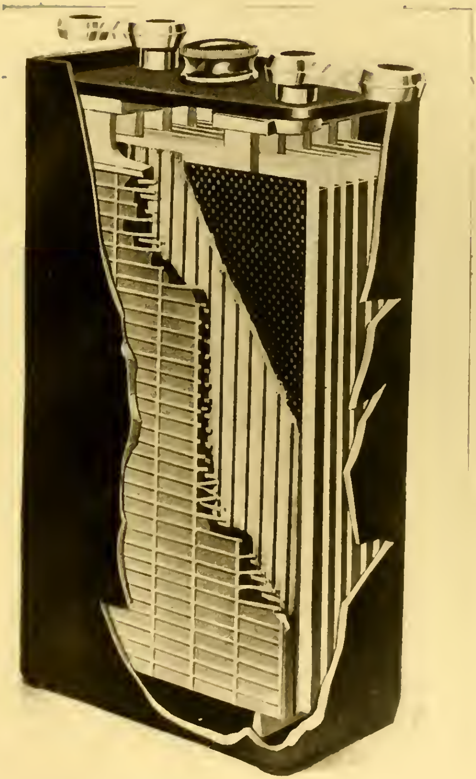
ILLUSTRATIONS.


VIVAX.
C. P. Rheostat.
C.P. Rheostat.
V
A
Lamp Rack.
EDISON.
110 Volt Main.

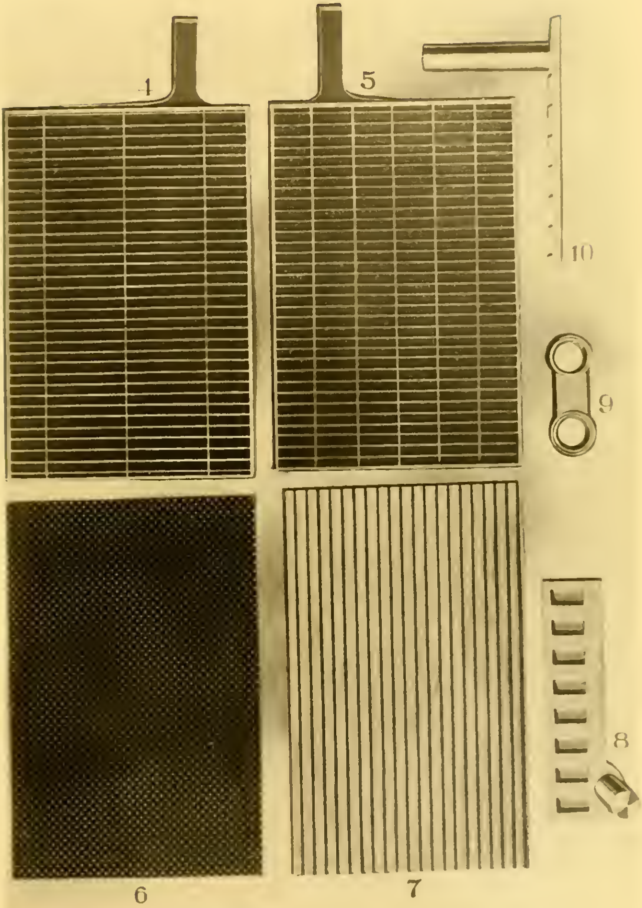


EDISON STORAGE BATTERY
"B_4" TYPE

VIVAX STORAGE BATTERY
NO. 19 TYPE



VIVAX STORAGE BATTERY
NO. 19 TYPE



DISCUSSION of RESULTS.

LITERATURE [illegible]

Our aim in the discussion which is to follow is to point out the different characteristics of the two types of batteries, and the advantage or disadvantage which the one has over the other.

The results show that the watt-hour efficiency is much higher for the lead battery than it is for the alkaline. This is due mainly to the high internal resistance of the Edison cell. This, therefore, would increase the heating of the Edison above that of the Vivax battery just as the tests have shown. The Vivax battery is also kept cooler due to the increased surface exposed to the air which promotes radiation of heat from the cell. It is interesting to note that for equal current rates the Edison battery heats up more on discharge than it does on charge up to the gassing point, while the reverse is true for the

lead cell.

It is claimed that the best working temperature of the batteries is 30 °C for the Edison and 35 °C for the Vivax. The batteries are less active at the lower temperatures while high temperatures shorten their lives. This would then naturally lead one to conclude that high rates are less injurious to the Vivax than they are to the Edison.

The capacity falls off, with increased rate of discharge, much more rapidly for the lead battery than for the Edison. The output per pound and the output per cubic foot are much higher for the Edison. In this respect the Edison has the advantage over the Vivax for vehicle work.

The Edison battery has to be filled with water more often than the Vivax. This is due to the small space above the plates in

the Edison cell. Furthermore, distilled water, which has not been exposed to the air for any great length of time, must be used for the Edison battery, while ordinary city water may be used for the Vivax. This is one serious objection to the use of the Edison battery where distilled water is not available.

Great care must be taken in handling the acid of the lead battery as it is very harmful to the hands and clothing. The electrolyte of the alkaline battery may be handled with less care as the injurious effects are not so marked. Then, too, the acid fumes given off the Vivax battery are harmful and objectionable, while for the Edison battery the fumes are less noticeable.

It is claimed by the makers that the Edison battery cannot be injured by over charging. This statement does not hold exactly for

the lead cell. A little overcharge occasionally is beneficial to the lead battery nevertheless, but it is not advisable to repeat the operation many times in succession.

The Edison people also state that their battery may be repeatedly short-circuited and discharged to complete exhaustion without decreasing the length of its life appreciably. It is, of course, a well established fact that this operation could not be performed with the lead battery without serious injury to the plates.

Again the statement is made that the Edison battery may be allowed to stand in a discharged condition for an indefinite period without fear of injury. The damage done to lead cells by sulphation through standing wholly or partially discharged is well known.

We regret to state that it was beyond the

scope of this work to varify the above statements in regard to the peculiar characteristics of the Edison cell. There is little known, outside of the Edison Laboratory, as to the exact workings of the alkaline battery. It still remains to be proved whether or not the Edison batteries may withstand the abuse and endurance as the manufacturers claim, and it is hoped this work may be continued in another similar paper.

SUMMARY.

General Comparison Table.

Descriptive	Vivax	Edison
Type of cell	"NP No.19"	"B4"
Ampere-Hour Rating	80	80
Number of cells	3	5
Rated volts per Set	6.5	6
Receptacle	Rubber	Steel
Plates	Lead	Steel
Positive Material	Lead Peroxide	Nickel Hydrate
Negative Material	Sponge Lead	Iron Oxide
Material retained by	Adhesion	Perforated Walls
Electrolyte	Sulphuric Acid	Potassium Hydrox
Crrosiveness	Strong	Weak
Sp.Gr. of Electrolyte (charged)	1.275	1.200
Gassing on charge	Violent	Violent
Product of Gassing	Explosive	Explosive
Product of Gassing	Corrosive	Harmless
Approximate Life, years	2.5	5
Internal Resistance per Ampere-hour capacity, ohms	0.0000491	0.0000923

Comparison at Normal Rates of 15 Amperes

Descriptive	Vivax	Edison
Maximum Cell Voltage at Charge	2.73	1.8
Minimum Cell Voltage at Discharge	1.80	1.0
Average Charge Voltage	2.332	1.670
Average Discharge Voltage	1.960	1.199
Time on Charge, Hours	7.675	7.125
Time on Discharge, hours	6.54	5.770
Watt-hour output per cell	192.3	103.8
Watt-hour Efficiency %	72.15	58.15
Watt-hour input per cell	266.5	178.6
Pounds per Cell	18.4	6.95
Watt-hours per Pound	10.45	14.93
Output per Pound, Ratio	.70	1.43
Ampere-hour Output	98.15	86.55
Ampere-hour Input	114.5	106.9
Ampere-hour Efficiency%	85.70	80.95
Over charge recommended %	25	100

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